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THE UNIVERSITY OF CHICAGO

DEPARTMENT OF METEOROLOGY

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1 July 1959 to 30 September 1959

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DESIGN OF A THREE-DIMENSIONAL MESO-METEOROLOGICAL NETWORK

Second Quarterly Technical Report
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To make a study and investigation into the capabilities of pre-existing and existing meso-meteorological networks and systems; to make analyses of these network data obtained; to revise and improve conventional meso-analysis techniques; and, based upon the data obtained, to submit a proposed design for a network system(s) best suited for the solution of three-dimensional meso-meteorological problems.

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PURPOSE

To make a study of the capabilities of existing and pre-existing networks for serving as frameworks for mesometeorological studies, and to design a network best suited for the solution of mesometeorological problems involving three-dimensional space and time. In order to accomplish this task, research will be performed in two phases.

Phase 1. Networks will be examined through data and through prior investigations on the basis of their adequacy to resolve mesometeorological phenomena. At the same time, revisions and improvements of analytical techniques will be made.

Phase 2. The network design will be based on the network size, station spacing, and the instrumentation necessary to contain, resolve, and record mesometeorological systems or processes in three-dimensional space and time and over various terrains.

ABSTRACT

(a-6) This study was undertaken for the purpose of determining the proper surface and upper-air station distances for the study of small mesometeorological systems such as cellular highs. Directed toward the design of an efficient three-dimensional mesometeorological network, analyses were made of 10-minute interval charts. They indicated an excessive density of surface network stations and the necessity for further consideration of this problem. It was also found that rawinsonde observations can be extremely important in revealing the vertical structure of cellular mesosystems, although the time of observations must be determined carefully according to the actual meteorological situations.

(b-1) A mesoanalysis was made of the gust lines that passed over the Lindenberg network area in Germany, using the data given in the published report by H. Koschmieder (1). The purpose of the study was to examine the capability of the network in resolving mesoscale systems. It was found that the station arrangement used in this network was superior to one more uniformly distributed because a larger area could be covered by the same number of stations.

(a-7) Data collected by the Soil Conservation Service over the Muskingum watershed in eastern Ohio and analysed by Byers (2) in 1942 in a pioneering study of nonfrontal thunderstorms were re-examined using recently developed techniques of mesoanalysis. The purpose of the study was to examine the capabilities of the network in the resolution of mesoscale systems and, within this framework, to determine the characteristics of various mesosystems that existed in the area.

PUBLICATIONS AND REPORTS

None

LECTURES

1. July 14 — "Analysis of Convective Systems," Henry A. Brown. Seminar, Department of Meteorology, University of Chicago.

2. September 21 — "Mesometeorology," Tetsuya Fujita. Seminar, Department of Meteorology, University of California at Los Angeles.

CONFERENCES

1. July 3 — Chicago, Illinois. Mr. Walter W. Frisbie, project monitor, discussed aspects of the contract with Dr. Fujita, Mr. Brown, and Mr. Omoto. Consideration was also given to the instrumentation of the New Jersey Microbarograph network.

2. July 9-16 — Missoula, Montana. Dr. Fujita investigated data collected by the Montana Skyfire network.

3. August 9-18 — Asheville, North Carolina. Mr. Omoto collected weather data for case studies of the Montana Skyfire network.

4. September 8-17 — Dugway, Utah and Fort Huachuca, Arizona. Mr. Brown investigated data collected by the Dugway Proving Ground network and the Fort Huachuca meso-meteorological network.

5. September 27 -October 3 — Chicago, Illinois. Dr. Stuart Bigler consulted with project personnel about the use of radar in meso-meteorological networks.

EVALUATION OF NETWORKS

Under Phase I (Signal Corps Technical Requirements SCL-5662) the analysis, investigation, and evaluation of pre-existing and existing networks and their data were continued during the second quarter. The following reports show the status of the research at the end of the quarter. Work under Phase II, the design of a network, was carried on concurrently with these analyses.

A. Ohio Thunderstorm Network (a-6).

1. Introduction:

As stated in the First Quarterly Technical Report (1), the purpose of this case study is to evaluate the Thunderstorm network as to its capability for studying the smallest mesometeorological systems. The case of August 13, 1947 was selected for this purpose and a series of 10-minute charts were analysed. In addition to the surface data, 11 rawin soundings were utilized in the analysis. The following report presents the full results of completed analysis.

2. General Weather Situation of August 13, 1947:

From a continental cyclone centered near International Falls, Minnesota, a warm front extended east over Lake Superior and a cold front ran southwest over Minneapolis, Des Moines, and Dodge City. The Ohio Thunderstorm network was located inside the warm sector formed by these two fronts. As shown in Fig. 1, scattered afternoon showers were moving over the network area. There was, however, no sign of organized development within 150 miles of the project area. The disturbances analysed in this case are considered to be isolated cellular systems belonging to the smallest of mesoscale systems.

3. Ten-Minute Interval Charts:

To find the limitation of accuracy in pressure correction for the purpose of drawing close-interval isobars, the standard mean pressure correction (3;4) was applied to the 1000-foot level pressure. Then a new technique, which may be called "linear tendency correction," was introduced. In this technique the three-hour pressure tendency (1430-1730 CST) plotted in the network chart was smoothed, and the departure from this smoothed pressure field corrected by using a linear function, which does not affect the mean pressure for the three-hour period. As a result of these two corrections, isobars could be drawn at 1/10 mb intervals on the 10-minute charts.

Figure 2 shows the legend used in the 10-minute charts. Surface and upper winds were plotted in such a manner that a barb and a flag represent 2 mph and 10 mph speeds, respectively. Winds aloft, with their position circles at the balloon locations for each map time, are represented by vectors relative to the earth's surface and to the radar echoes, whose movement was north-northwest at 6 mph. In addition to the front of outflowing cold air from the active thunderstorm cells, the chart shows a front of back current pushing away from the leading edge of the cold air.

Details of the wind field at 1510 CST are presented in Fig. 3. It is of interest to see that wind directions over the network area were quite different from those which appear in the regular synoptic chart (Fig. 1). It seems that the winds in the vicinity of the small high to the south of the network were converging toward the high. The isobars indicate the existence of a low-pressure area which was maintaining the converging winds at the surface.

Ten minutes later, at 1520 CST, a small echo started developing over the southwest corner of the network where the leading edge of the cold air outflow from cold dome No. 1 was situated. Detailed features are shown in Fig. 4; however, it is very difficult to determine whether or not the initiation of the new echo was associated directly with the mechanical lifting at the boundary of dome No. 1. If so, it is necessary to account for the fact that new echoes did not form around the boundary.

Another cell northwest of the network was a rather inactive one. Had it been accompanied by a cellular mesohigh, it would have produced an appreciable surface outflow, which some of the network stations would have picked up. This was not the case, however.

During the next ten minutes, five rawinsondes were released from the network upper-air stations about eight miles apart. The relative and absolute wind vectors are shown in the chart for 1530 CST (Fig. 5). The 800 mb relative winds shifted almost 90 degrees, indicating that winds at this level were blowing from northwest of the radar echoes. It is extremely interesting to note that the 900 mb relative winds form a flow pattern around cold dome No. 1, which would have acted as an obstacle to the flow. From these wind structures it may be concluded that the air converging into the base of the major convective cloud came mainly from a very shallow layer near the ground (about 1000 feet above sea level) and rose to the 900 mb level. The thickness of the layer would probably be less than 3000 feet.

As the balloon went up, the absolute wind shifted northwest, resulting in strong northwesterly relative winds between the 700 and 500 mb levels. Figure 6 shows these winds. During the ten minutes prior to 1540 CST, a pressure dome accompanied by a strong cold-air outflow was formed directly under the large echo. The top gust reached as high as 25 mph.

By 1550 CST (Fig. 7) the cold air outflows beneath the two radar echoes joined together, and the area covered by the cold air was already twice as large as the echo area. Isobars drawn for 1/10 mb intervals proved very useful in representing these small mesometeorological disturbances at the surface. On the other hand, the back current front, radiating outward from the leading edge of the cold air, had separated from the edge as much as two miles by this time. The cause of this front will be discussed later.

The 400 mb absolute winds (Fig. 8) were very similar, especially in direction, to the surface winds directly below them. This would be only coincidental. Cold domes No. 2 and 3 merged into a system covering almost one-half the network area. Two active echoes accompanied by an extremely divergent wind field still remained in the system.

The last 10-minute chart in this series (Fig. 8) reveals a strong southeasterly wind, which would have been effective in producing cirrus streamers from the cumulo-nimbus tops above mesohighs No. 2 and 3. It is amazing to note that the remnant of cold dome No. 1 could still be seen. From this fact, it is postulated that domes 1 and 2, in their mature stage at this map time, would have continued to grow in diameter for at least a few hours.

4. Pressure Profile through Cellular High:

Assuming that cold dome No. 2 was a pressure disturbance superimposed upon the isobar pattern shown in Fig. 1, a southwest-northeast orientation was selected for making 5 to 10 minute interval pressure profiles. The results are presented in Figs. 10 and 11.

The first profile was made at 1510 CST, a few minutes before the first echo was formed above the leading edge of cold dome No. 1. As soon as the first echo was initiated, the pressure beneath the echo rose a few tenths mbs. The curve eliminating domes No. 1 and 2 indicates a low pressure system which would have maintained the converging wind system beneath the cloud base.

The first downdraft was assumed to have reached the ground between 1525 and 1530 CST, when the amount of nose pressure reached 6/10 mb. The diameter of the downdraft, as indicated in the figures, grew rapidly; however, the drop in nose pressure appeared rather rapidly. One would probably expect to see a pressure dome for less than 10 minutes. The dome pressure field then flattened out at a rather low rate compared to the quick dissipation of the nose.

Figure 12 shows a model of the isolated thunderstorm established through this case study. There is no basic change in the model described in <u>The Thunderstorm</u> (5) except for the addition of a pressure profile, which is closely related to the low-level convergence field and the back current front. As seen in the figure, there was a slight pressure rise ahead of the leading edge of the cold air. As a result, the converging surface flow did not recover enough pressure to overcome the anticyclonic gradient outside the boundary of the mesosystem. Because the surface friction continuously drops, the total pressure must be defined by

$$P = p + \tfrac{1}{2}\rho v^2$$

where P is the total pressure; p, the pressure; ρ, the density; and v, the velocity.

On the other hand, the air slightly above the surface flow still maintains a larger total pressure than the surface air and is capable of building up its pressure as its speed decreases. As a result, winds overlaying the surface air overshoot the point where the surface air stops and then subside, moving back to the back current front along which these two currents meet.

5. Conclusions:

This particular case study was undertaken in order to evaluate the capability and limitations of the Thunderstorm Project data for the study of cellular mesoscale systems. It was found that the data, especially pressure values, permit us to draw even 1/10 mb isobars through the network area. It is, of course, necessary to be most careful in applying proper mean-value and linear-tendency corrections. It is evident, therefore, that the network was certainly capable of supplying data for the study of the smallest of mesoscale systems, such as cellular thunderstorm highs, cellular divergence patterns, back current fronts, etc.

Upper air observations made by rawinsondes approximately eight miles apart failed to reveal the wind structure inside the three cellular highs appearing in the network area. Only one out of eleven ascents went through a mesohigh, but the instrument failed at the 820 mb level.

It seems apparent that the capability of rawinsonde cannot be determined by the average station distance or the frequency of observations. If observations are not taken at appropriate times and stations, the use of the data is limited. Therefore, a proper control of observations is required. This problem will be discussed in detail using a special statistical method now under development.

B. Lindenberg Network (b-1).

1. Description of the Network:

During the summers of 1939, 1940, and 1941, special observations of wind gusts and related phenomena were made in Germany over the area southeast of Berlin (Figs. 13 and 14). Most of the observational stations were located along two lines, one oriented northwest-southeast, the other oriented southwest-northeast. The central station of the network was located at Lindenberg, near the intersection of the two lines. The network extended over a basin-like area surrounded by hills 400 feet above the average station height. One hundred miles to the south were mountains ranging over 3000 feet msl. Table 1 indicates the types of observation made by each of the 27 stations.

2. General Description of Gusts in the Area:

The results of observation were published in 1955 by H. Koschmieder as "Ergebnisse der Deutschen Böenmessungen 1939/41" (6). From this report the characteristics of gusts over the network area can be summarized as follows:

1. Most of the gust lines moved in directions between east and southeast; about 1/5 of the lines moved in directions between north-northeast and north-northwest.
2. Wind shifts accompanying the gust lines were in many cases not very appreciable.
3. Most of the gusts occurred at Lindenberg between 1600 and 2100.
4. The gust lines passed through the network in about two hours, at a speed of about 20 knots.
5. Each gust line was accompanied by a temperature drop, large in the case of the afternoon gusts and small during the evening gusts.
6. Generally, less than 0.20 inches of rain was associated with the passage of a single gust line, and in only a few cases was the maximum more than 0.50 inches.

LINDENBERG NETWORK STATIONS, 1940-41

Number	Name of Station	Wind	Temperature	Rain
1a	Tempelhof	x	x	
1b	Neuzittau	x	x	x
1c	Neustahnsdorf	x	x	x
1d	Reichenwalde	x	x	x
1e = Li	Lindenberg	x	x	x
1f	Bahrensdorf	x	x	x
1g	Weichensdorf	x	x	x
1h	Reicherskreuz	x	x	x
1j	Guben	x		
2a	Dahme	x		
2b	Schönwalde	x	x	x
2c	Neulübbenau	x	x	x
2d	Schwenow	x	x	x
2e = Li	Lindenberg	x	x	x
2f	Rassmannsdorf	x	x	x
2g	Biegen	x	x	x
2h	Frankfurt/Oder	x	x	
2j	Drossen	x		
3a	Wriezen	x		
3b	Müncheberg	x	x	x
3c	Fürstenwalde/Spree	x	x	x
3d	Sarrow	x	x	
Co	Cottbus	x	x	x
Kd	Kummersdorf		x	
Rd	Rangsdorf	x	x	
Wn	Wernuechen	x	x	

3. Case Study of the Gusts on July 3, 1940:

The Koschmieder report presented records of wind, temperature, and humidity observations for 30 cases. The analyses included temperature distribution and isochrones of the gust lines and of temperature drops; the amount of temperature drop and the total amount of precipitation associated with each gust was plotted for all the stations. From the information given in the report, an analysis was made for the case of July 3, 1940.

On this day three distinct gust lines passed over the area, two in the afternoon and one later in the evening. Isochrones of these lines are shown in Fig. 15 and 16. The two afternoon gust lines crossed over the central part of the network (Fig. 15). Both of these lines are considered to be boundaries of small mesosystems initially developing northwest and south of the network area. One of the heaviest rains during the entire period of observation from 1939 through 1941 occurred at the intersection of the two boundaries. The total amount of precipitation due to these gust lines is plotted in Fig. 16. The gust line of the late evening seemed to be a cold front.

4. Gust Lines in the Afternoon of July 3:

Figure 17 shows wind and temperature distribution at 1600. The northwest gust line had just passed station 1a, where a northwest wind of about 30 knots was measured at the passage of the line. A weak south-southwest wind prevailed east of the gust line. Ahead of the line temperatures ranged between 26° and 29° C. Throughout the precipitation network (the rectangular area indicated in the chart) no rain was observed at this time.

Figure 18 shows the wind and temperature distribution at 1650, when the northwest gust line and the gust line from the south almost coincided southwest of Lindenberg. There was rain over this area, and at Lindenberg the temperature dropped 8.5° C as the northwest line passed.

At 1700 (Fig. 19) the gust line from the south continued to move northward, intersecting the northeast gust line. The rain area was expanding and moving northeastward. At 1710 (Fig. 20) there was a strong west-northwest wind at Lindenberg, despite the fact that the station was located to the rear of the south gust line and, therefore, in the area of southerly wind. Occurring in a small area, this strong wind seemed to be related to the small gust line resulting from the heavy rain at the intersection of the gust lines.

In the chart for the situation at 1720 (Fig. 21) this west-wind area had moved east-southeast of Lindenberg, and a relatively large area of calm appeared near the intersection of the gust lines. The rain area was still moving northeastward at this time.

Analysis revealed that the gust lines appearing in these charts were the boundaries of mesosystems. The eventual weakening of wind speeds indicates that the systems had come to their last stage. However, new development of rain at the intersection produced new cold air which spread into the old systems.

5. Gust Line of the Late Evening of July 3:

Although isochrones for this gust line (Fig. 16) resembled those for the northwest gust line mentioned above, there was an essential difference between the two. The afternoon gust line was the boundary of a mesosystem, while the evening gust line was the wind-shift line of a cold front. In fact, the northwest wind accompanying the passage of the northwest gust line of the afternoon lasted only an hour or so even at the stations outside the passage of the gust line from the south. On the other hand, the northwest wind accompanying the evening gust line lasted at least three hours. The actual duration of northwest wind cannot be determined from Koschmieder's report, which includes data on wind direction only for a three-hour period following the evening gust.

Figure 22 shows the situation at 2130, when the gust line was almost in the middle of the network. Wind arrows with circles indicate the stations actually measuring winds; all other arrows indicate winds computed from the continuous records of gust-line velocity. The figure again shows the appearance of small-scale wind disturbances inside the rain area. This rain area was moving northeastward while the gust line was moving east-southeastward.

Such a phenomenon, often noted by meteorologists, was explained by Newton and Katz (7). A temperature drop of 2° C was the largest fall observed associated with the passage of this gust line.

6. Conclusions:

Investigation of the gust lines of July 3, 1940 as well as other cases presented in the Koschmieder report revealed that the gust lines in the Lindenberg network were, in most cases, the boundaries of mesosystems. These mesosystems were approximately the same size as those found in the area of the Japanese thunderstorm network (1). The Lindenberg network was too small for the study of mesoscale systems appearing in the area.

Two mesosystems, each producing a gust line, were formed in the afternoon of July 3. Both were associated with scattered rain areas ahead of the cold front, which passed over the network in the late evening to produce the third gust line of the day. The radius of curvature of these gust lines suggests that the centers of the systems were outside the area of analysis. The rain area appearing in the charts developed at the intersection of the gust lines and produced a small gust line, which failed to develop as much as the others because of its location inside the mesosystems producing the major gust lines.

With approximately the same number of observational stations, the Lindenberg network covered a larger area than the Japanese network. Analyses of the same accuracy were nevertheless possible because of the superior station distribution in the Lindenberg area. However, the Lindenberg arrangement might not be adequate when the distance between the end stations of each line (AC in Fig. 23) is very large in relation to the distance between adjacent stations along the line (AA' of Fig. 23).

C. Muskingum Soil Conservation Service Network (a-7).

1. Introduction:

The techniques of mesoanalysis proposed by Fujita (3) have proved to be most valuable in representing weather systems ranging in size from tens to hundreds of miles. Inasmuch as the regular Weather Bureau observation network has a surface-station spacing on the order of a hundred miles and upper-air observation stations even more widely spaced, there has been little opportunity to study mesoscale systems except in connection with special weather networks.

Two networks provided the major part of the data which have been and are currently being analysed by the University of Chicago group: the Thunderstorm network (see Section A of this report), which operated only during 1946 and 1947, and the Weather Bureau Severe Local Storms network, which is still in existence.

In order to determine the characteristics of mesoscale systems under varying conditions of latitude, topography, land-water contrasts, etc., it has been necessary to search for weather networks which have been operated in the past, for whatever reason, and to reanalyse their data in the light of present-day knowledge of mesometeorology. In addition, this procedure provides an excellent check on the efficiency of the network in obtaining data that can be used in mesoanalysis.

Such networks were, for example, the Japanese Thunderstorm network (1), the New Jersey Microbarograph network (1), the Lindenberg network (which has been examined in Section B of this report), and the Muskingum network.

The Muskingum network, located in east central Ohio, was operated by the Soil Conservation Service and the Works Progress Administration during the years 1937-1941. The primary purpose of the network, which has been studied extensively (8), was to provide data on rainfall over the Muskingum watershed. Byers (2) also utilized the observational data from the network in an early study of nonfrontal thunderstorms in 1942. The data presented in his report were most valuable in allowing a re-examination of this network for the purpose of determining the sizes of mesosystems in this area and the capabilities of the network in resolving mesometeorological systems.

2. Network Description:

The principal method of obtaining data over the 6500 square-mile area was through observers situated at 131 stations with an approximate eight-mile separation (Fig. 24). The Thunderstorm Project network is shown in the lower right for comparison of sizes). Observations, taken at half-hour intervals during daylight, included wind direction and speed, weather and sky cover, dry and wet bulb temperatures, and rainfall.

The general topography of the network can be seen in Fig. 25. The thousand-foot contour illustrates the wide variability of height over relatively short distances, and several high points indicate the range of heights. Stations appeared to be well distributed with respect to topography; wind observations, however, are, as would be expected, seriously affected by location.

3. Large-Scale Weather Situation of July 16, 1957:

The large-scale weather pattern at 1330, the time of initial thunderstorm occurrence in the network area, revealed that temperatures ranged from the middle 80's to the middle 90's, with dewpoint temperatures ranging from the middle 60's to the middle 70's. A southwest-northeast cold front just west of Chicago at 1330 moved east almost to Detroit by 1930 (Fig. 27).

Initial thunderstorm occurrence was confined to the northwest portion of the network. Smoothed isochrones of the boundaries of the severe weather can be seen in Fig. 26. Originating at 1330, the system had, by 1930, grown to affect an area with a mean diameter of approximately 400 miles.

The following half-hourly maps present a more detailed analysis of weather that existed in the network area from 1330 until 1600.

4. Mesoscale Weather Situation:

Prior to the plotting and analysis of the following charts, time-section sheets for each station were prepared from the half-hourly observations. In this manner the approximate times of precipitation, temperature drop, and wind direction change were obtained. In addition, certain peculiarities which were due to station location were easily found.

The analysis will show the boundaries of the mesoscale systems, isotherms for every 5' interval, wind direction and speed, smoothed streamlines of surface wind, and rainfall areas.

At 1330 (Fig. 28) three systems are apparent, with a new development occurring in the northeast and one moving into the northwestern portion of the network area. The largest system is evidently the oldest and apparently originated in the vicinity of Mansfield. The only large temperature contrasts occur in a narrow band located just within the boundaries of the systems. It is of interest to examine the wind field as represented by the station reports. The variations due to station location and smaller-scale wind fluctuations are easily seen. In general the undisturbed wind flow is from the southwest. As would be expected, the wind flow within the mesosystems appears to be diverging; however, thirty-minute observations of wind direction and speed are insufficient to determine in more than a very general manner the details of the disturbed flow patterns.

At 1400 (Fig. 29) three systems are still contained within the network. Heaviest rainfalls are confined to the southeastern portions of the systems. There are diverging wind fields within the systems and a general undisturbed flow from the southwest over the major portion of the network.

At 1430 (Fig. 30) all the systems except the first one, which formed near Mansfield, have moved very rapidly south and east. All systems show continued expansion. Heaviest rainfall has occurred in the system located in the center of the network and the one pushing in from the northwest. Three new developments are occurring in the network area to the south of the older systems and another system is entering the network area from the southwest.

By 1500 (Fig. 31) it has become difficult to delineate the interior structure of the large composite mesoscale system because of the large time interval between observations; moreover, gradients within the system are much less apparent than those along the leading edges. The composite northern boundary of the system is diffuse and stations located in the northern area show only a gradual, slightly more than diurnal, temperature decrease. The original systems have expanded to considerable size and the newly developed systems are most apparent in the southwestern portion of the network.

Rainfall amounts on the order of .80" in one-half hour were reported in conjunction with the large system located in the central portion of the network.

The leading edge of the composite mesosystem has, at 1530 (Fig. 32), continued to advance very rapidly toward the southeast and much more slowly toward the north. Temperatures outside the disturbed area range in the middle 80's, while most of the disturbed area is represented by surface temperatures in the high 60's.

The final map (1600 EST, Fig. 33) shows that almost the entire network area is covered by air which has been modified by thunderstorm activity. The leading edge of the mesosystem is still advancing most rapidly toward the southeast, where thunderstorm activity is concentrated.

5. Conclusions:

Results of the analyses revealed that initial thunderstorm activity occurred shortly before 1330, July 16, 1937, in the northwestern portion of the network. With time, activity intensified in the original systems and new developments began rapidly. In a few cases short-lived systems developed behind the boundaries of older systems, but the majority of important new systems developed ahead and to the southeast of the old systems. Thunderstorm development in the new and old systems was concentrated along their southeastern edges.

Thus the composite mesosystem swept across the network from northwest to southeast at an average speed of about 25 mph and spread more slowly northward, covering the network in two and a half hours. The faster moving southeast portion of the boundary was clearly identified by large temperature drops and wind direction and speed changes; the northward moving boundary was more diffuse and much more difficult to define. In the earlier hours of development the individual cellular systems were easily distinguished, but as activity intensified and the systems spread and merged with adjacent systems, the inner boundaries became diffuse because of similar air-mass characteristics and only the leading composite edge of the systems was easily defined. The sizes of the systems, defined in terms of mean diameter, ranged from lower limits of 10 to 15 miles in the earliest detectable stages of development to approximately 80 miles in the two and a half hours of observation.

In determining the efficiency of a network for resolving mesoscale systems, a number of factors should be considered. Among the most important are station spacing and area covered by the network, the type and quality of instrumentation, and the time intervals of observations. It must be recognized that these factors will also be directly related to the locale and topography of the area to be studied.

The station spacing of the Muskingum network appeared to be almost ideal for the study of the gross features of a cellular thunderstorm system and the fine details of the interaction and amalgamation of cellular systems into larger composite mesoscale systems. The area covered by the network also appeared to be almost ideal in this case in that it was large enough to contain the initial development of the systems and their subsequent growth and motion at speeds of 25 mph. The analyses and the isochrone chart (Fig. 26) suggest, however, a further problem: the relation of the large "squall line" mesosystem with the macroscale weather pattern.

Little can be said concerning the types and quality of instrumentation that made up the network since by present-day standards it would be considered antique, except for the advantage of having 131 visual observations over a 6500 square mile area. For a mesoscale network, however, this human factor proved to be a disadvantage, for it allowed the stipulation of observations at 30-minute intervals. The need for more frequent observations—at least 4 per hour for the speeds of these systems and preferably more for notation of new development—became quickly apparent at the first stage of the data processing, i.e., in preparing station data sheets and isochrone analysis. On the other hand, a more completely equipped network located in such an area could be expected to yield a tremendous amount of knowledge concerning mesoscale processes.

Further discussion of this network will be included in the final design report.

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3. Fujita, T., 1955: Results of detailed synoptic studies of squall lines, Tellus, 1, 405-436.

4. Fujita, T., H. Newstein, and M. Tepper, 1956: Mesoanalysis, an important scale in the analysis of weather data. Research Paper # 39, U. S. W. B.

5. Byers, H. R., and R. R. Braham, Jr., 1949: The thunderstorm. Govt. Print. Off., Washington, D. C.

6. Koschmieder, H., 1955: Ergebnisse der deutschen böenmessungun 1937/41. Friedr. Vieweg and Sohn, Braunschweig, 86 pp.

7. Newton, C. W., and S. Katz, 1958: Movement of large convective rainstorms in relation to winds aloft, BAMS, 39, 129-136.

8. 1947: Thunderstorm rainfall. Hydrometeorological Rep. # 5, Waterways Experiment Station, Vicksburg, Mississippi.

PROGRAM FOR NEXT QUARTER

Under Phase 1, the evaluation of networks and network data will be continued. The case studies of April 6-7, 1958 and November 28-29, 1958 (New Jersey Microbarograph network) and August 21-22, 1958 (Montana Skyfire network) will be completed. Data collected by the Fort Huachuca Mesometeorological network and the Dugway Proving Ground network will also be plotted and analyses begun.

Under Phase 2 (design of a network), work will be continued concurrently with the above analyses in determining knowledge concerning the three-dimensional space and time variations of various mesosystems.

PERSONNEL

Fujita	Principal Investigator	130 hours
Brown	Meteorologist	385
Omoto	Meteorologist	195
Auxer	Meteorological Aide	390
Ellin	Meteorological Aide	95
Kirwan	Meteorological Aide	245
Ridinger	Secretary	485

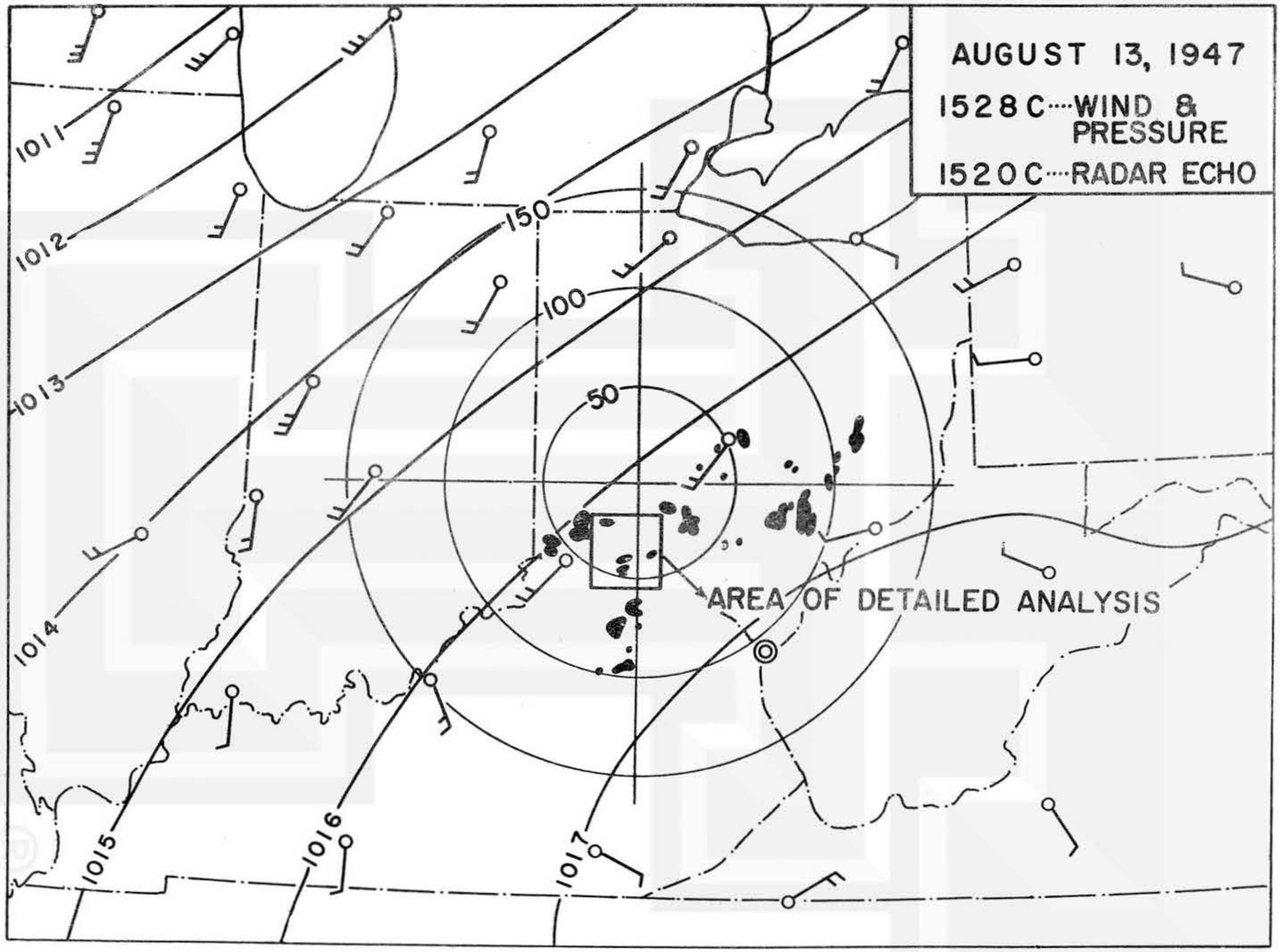

AUGUST 13, 1947
1528 C····WIND & PRESSURE
1520 C····RADAR ECHO
1011
1012
1013
1014
1015
1016
1017
150
100
50
AREA OF DETAILED ANALYSIS

FIG. 1

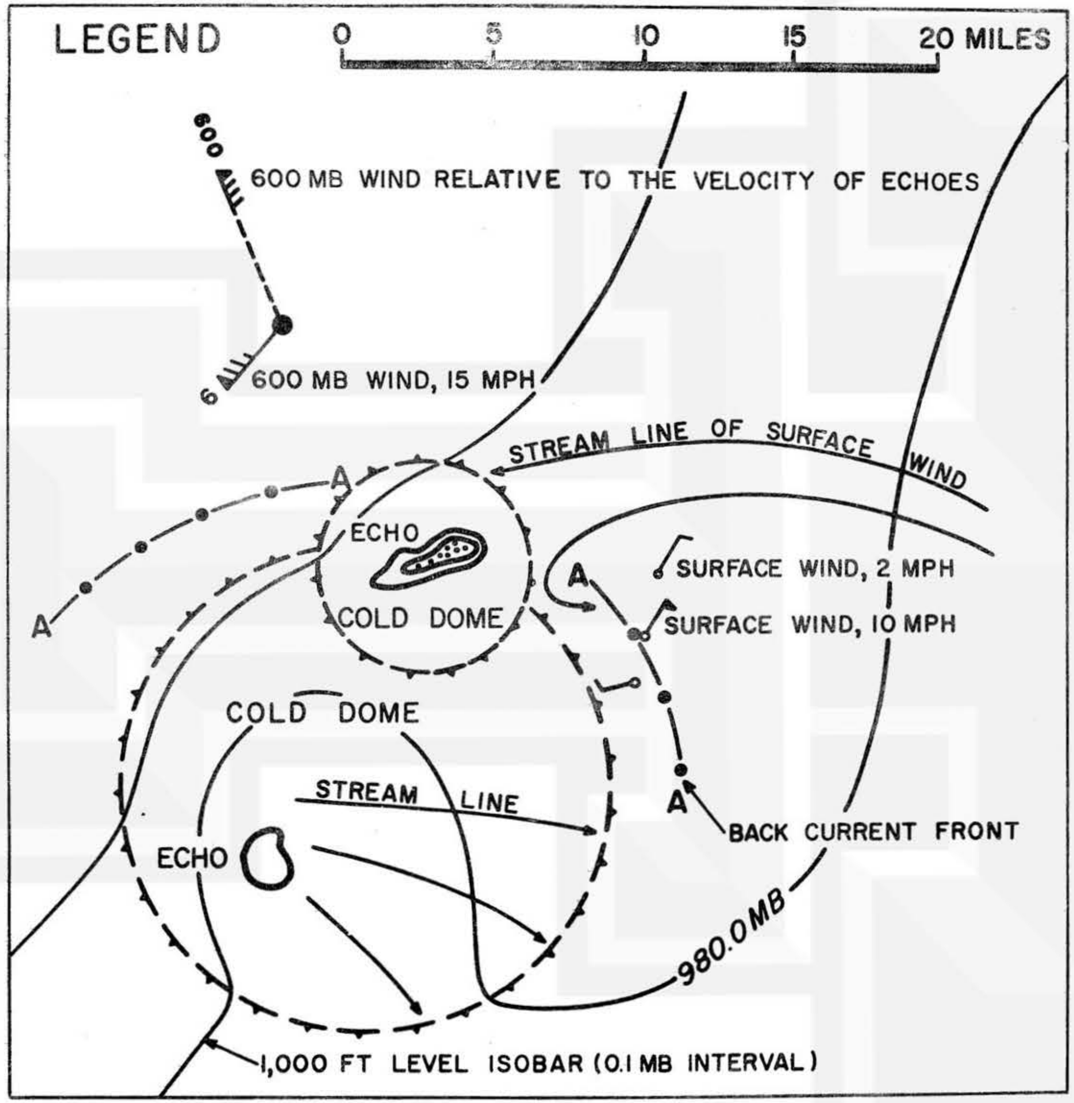

LEGEND
0
5
10
15
20 MILES
600
600 MB WIND RELATIVE TO THE VELOCITY OF ECHOES
600 MB WIND, 15 MPH
STREAM LINE OF SURFACE WIND
A
ECHO
COLD DOME
SURFACE WIND, 2 MPH
SURFACE WIND, 10 MPH
COLD DOME
STREAM LINE
ECHO
BACK CURRENT FRONT
980.0 MB
1,000 FT LEVEL ISOBAR (0.1 MB INTERVAL)

FIG. 2

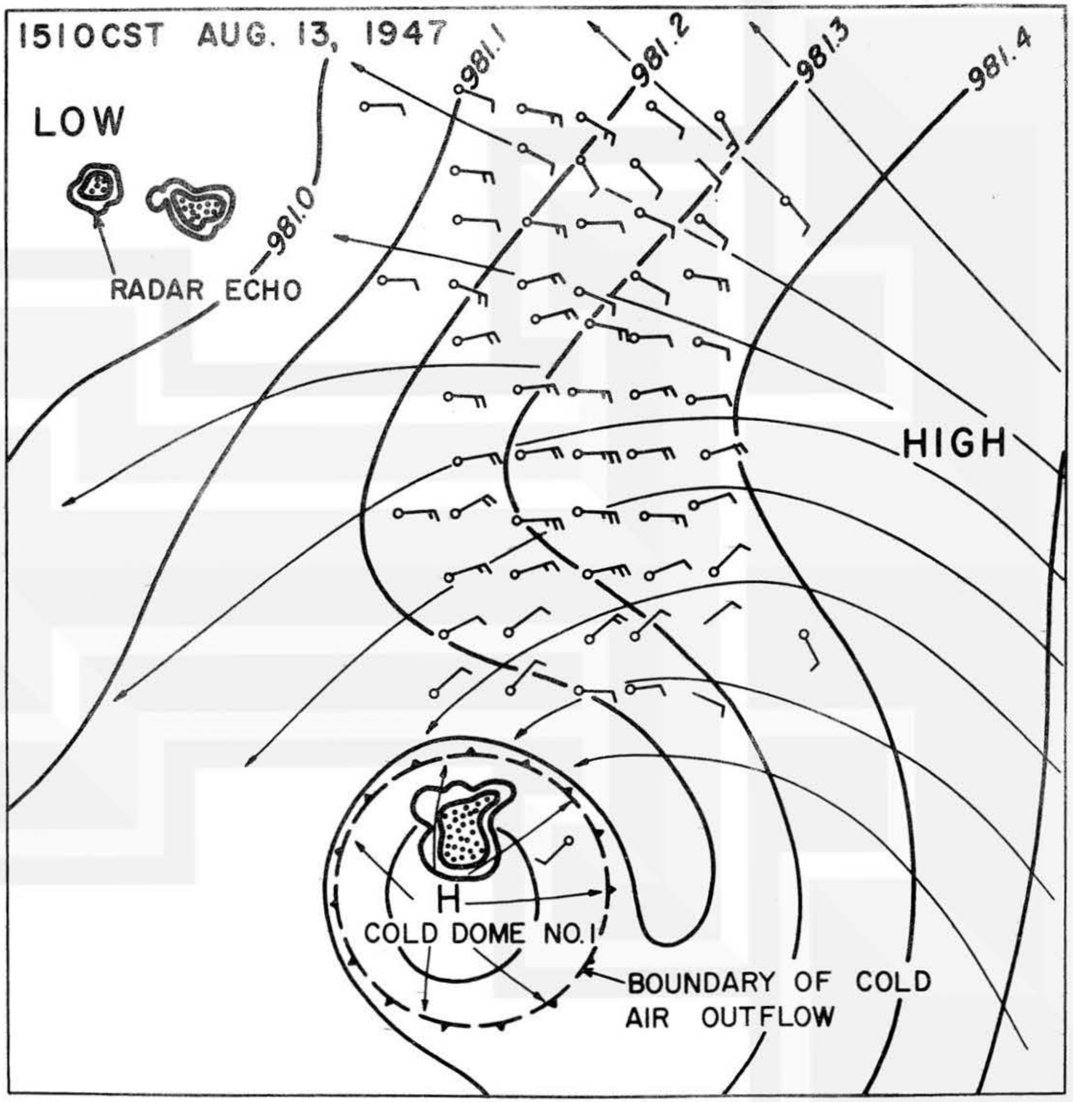

1510 CST AUG. 13, 1947
981.0
981.1
981.2
981.3
981.4
LOW
RADAR ECHO
HIGH
H
COLD DOME NO. 1
BOUNDARY OF COLD AIR OUTFLOW

FIG. 3

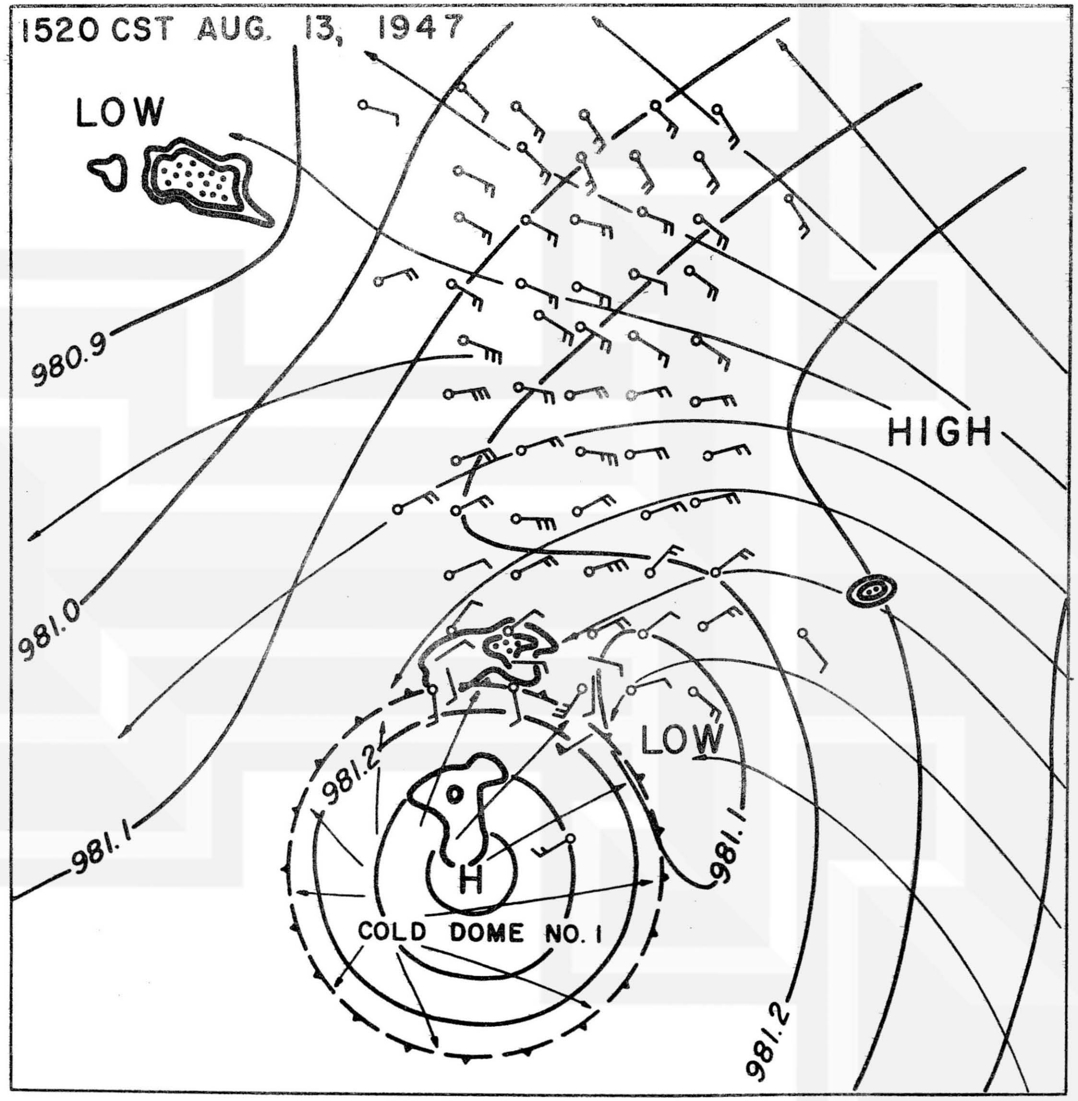

1520 CST AUG. 13, 1947
LOW
980.9
981.0
981.1
HIGH
981.2
LOW
H
COLD DOME NO. 1
981.1
981.2

FIG. 4

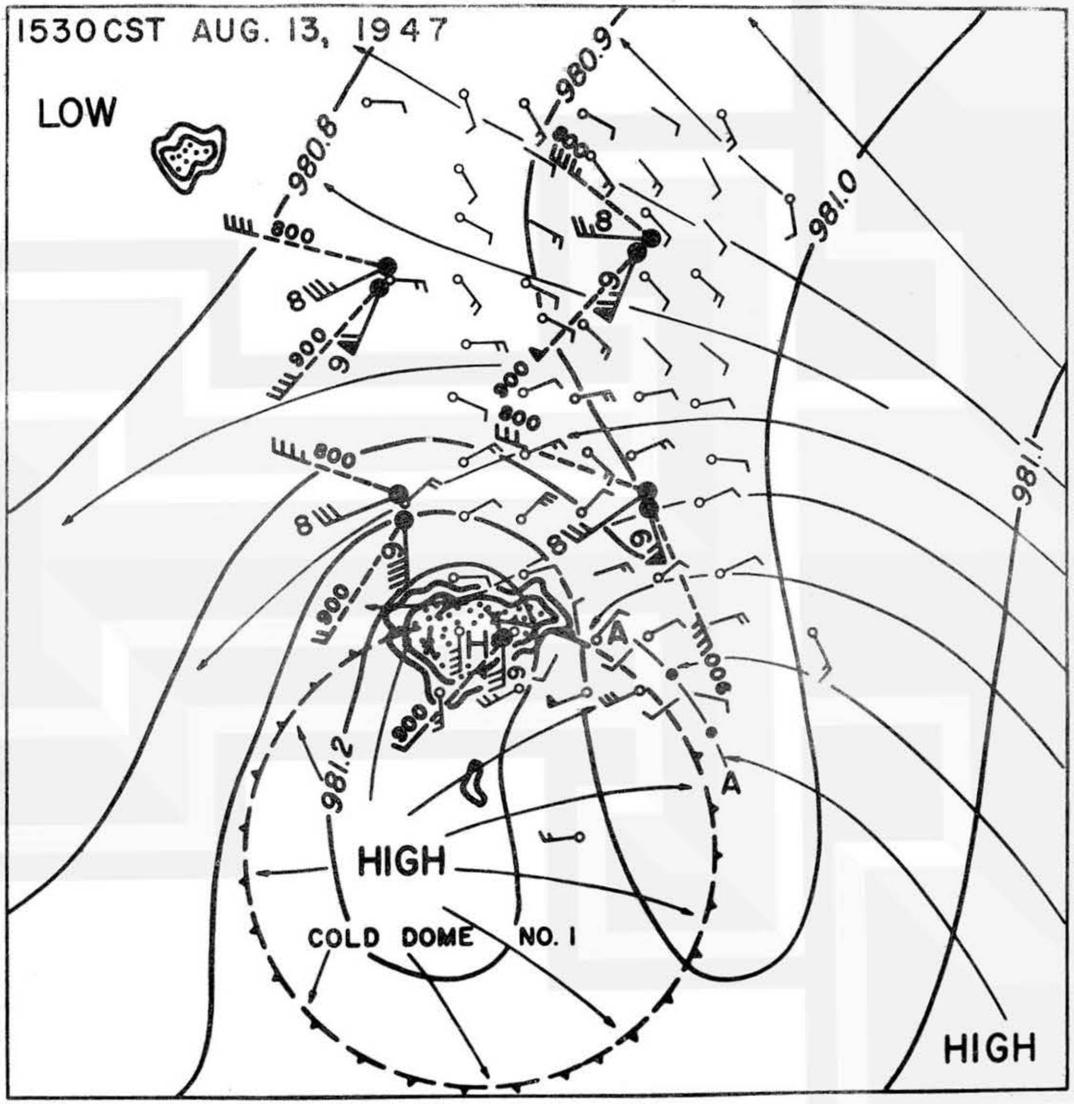

1530 CST AUG. 13, 1947
LOW
980.8
980.9
981.0
981.1
981.2
HIGH
COLD DOME NO. 1
HIGH
A
A

FIG. 5

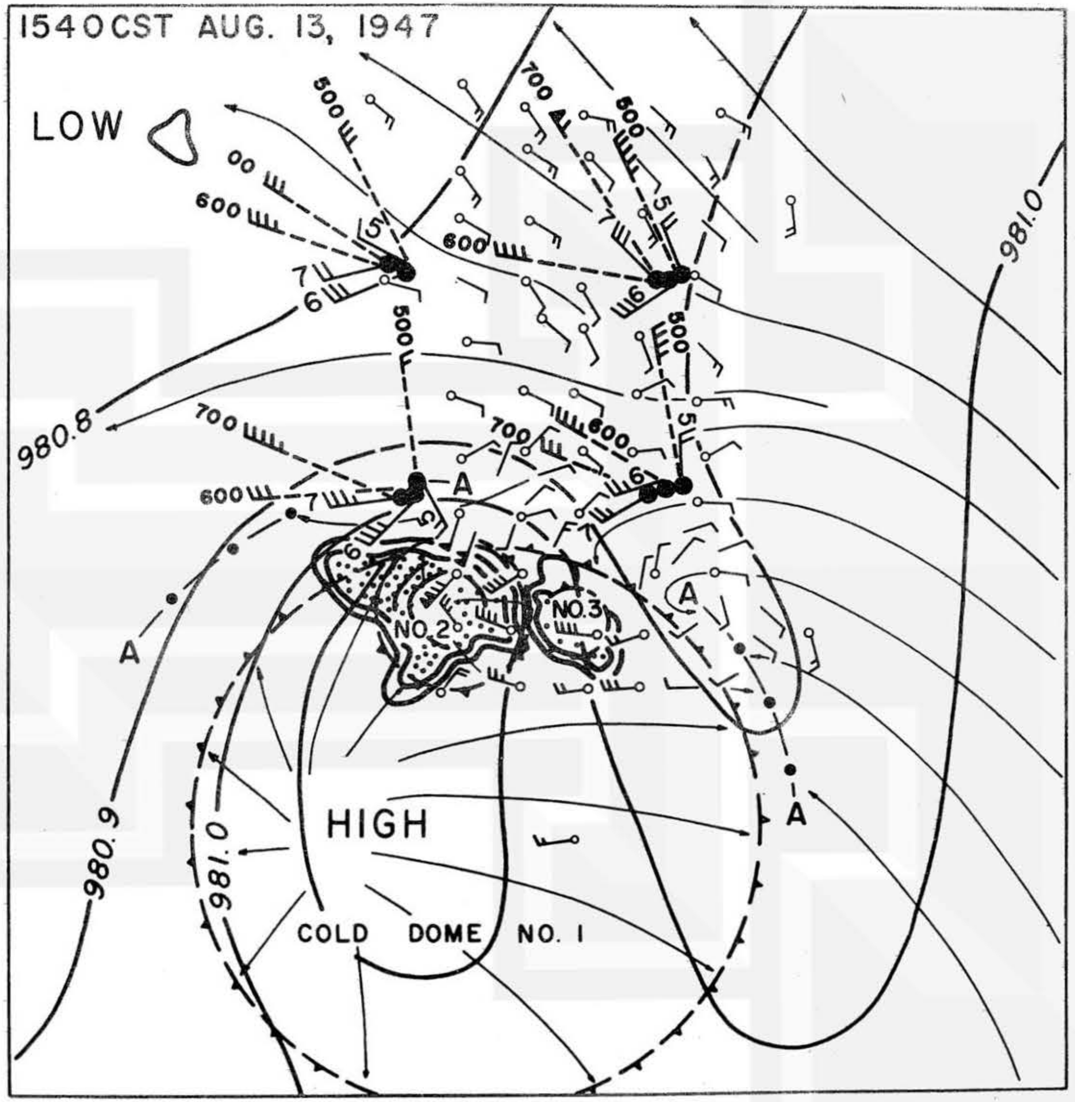

1540 CST AUG. 13, 1947
LOW
HIGH
COLD DOME NO. 1
NO. 2
NO. 3
980.8
980.9
981.0
981.0
A
A
A
A

FIG. 6

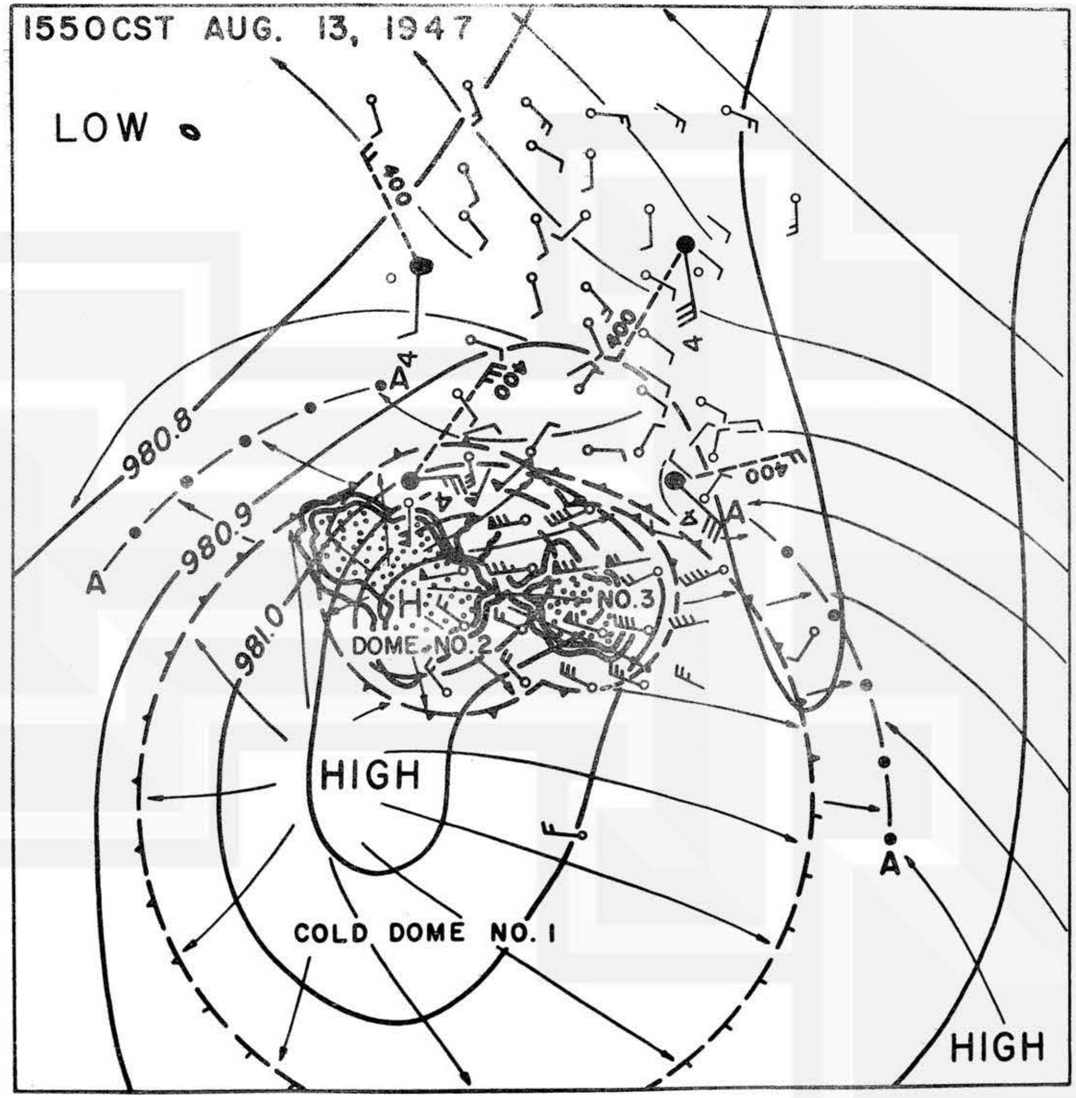

1550CST AUG. 13, 1947
LOW
400
400
400
400
980.8
980.9
981.0
A
A
A
A
DOME NO. 2
NO. 3
HIGH
COLD DOME NO. 1
HIGH

FIG. 7

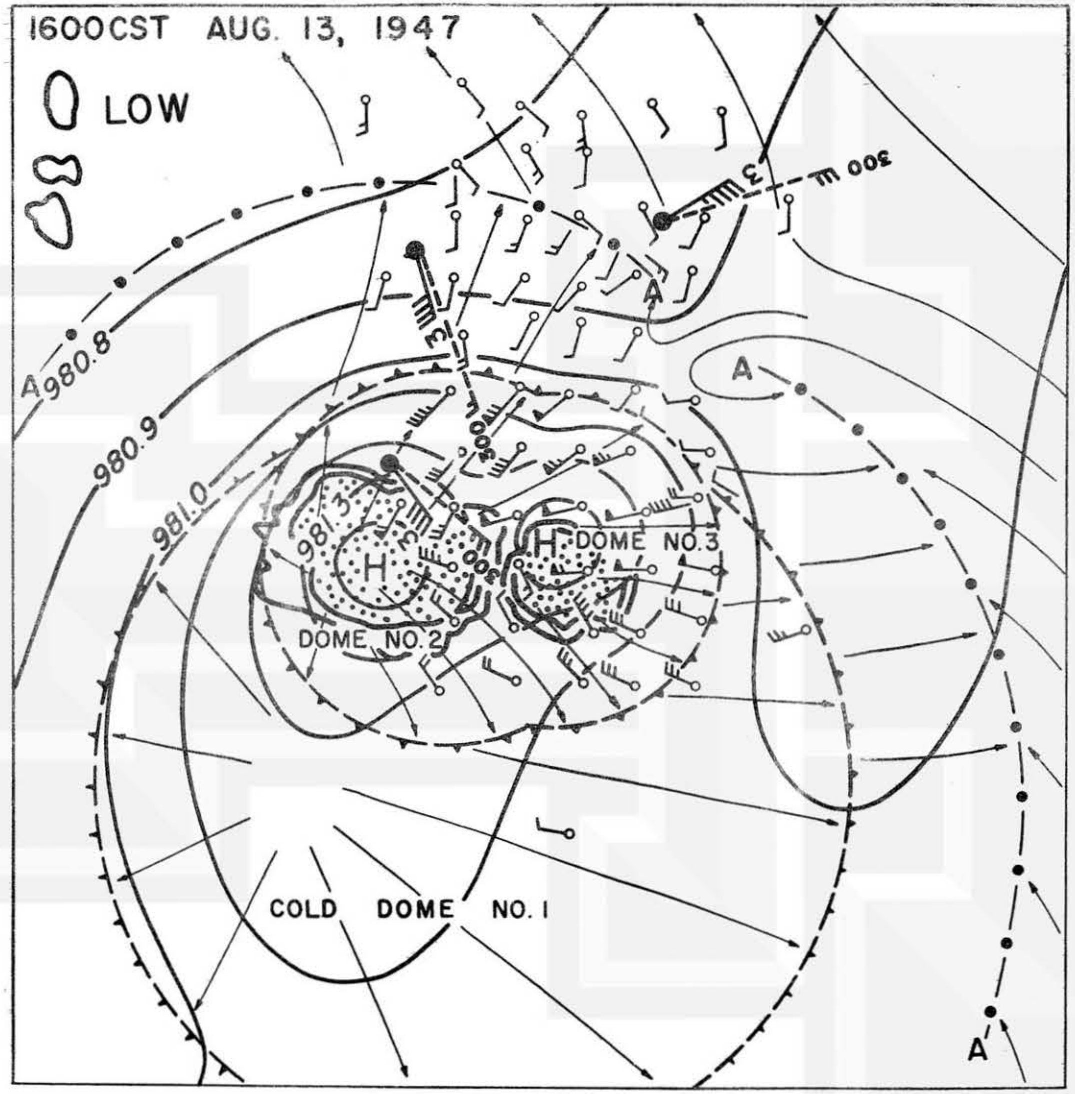

1600CST AUG. 13, 1947
LOW
980.8
980.9
981.0
981.3
300 m
H
H
DOME NO. 2
DOME NO. 3
A
A
A
COLD DOME NO. 1

FIG. 8

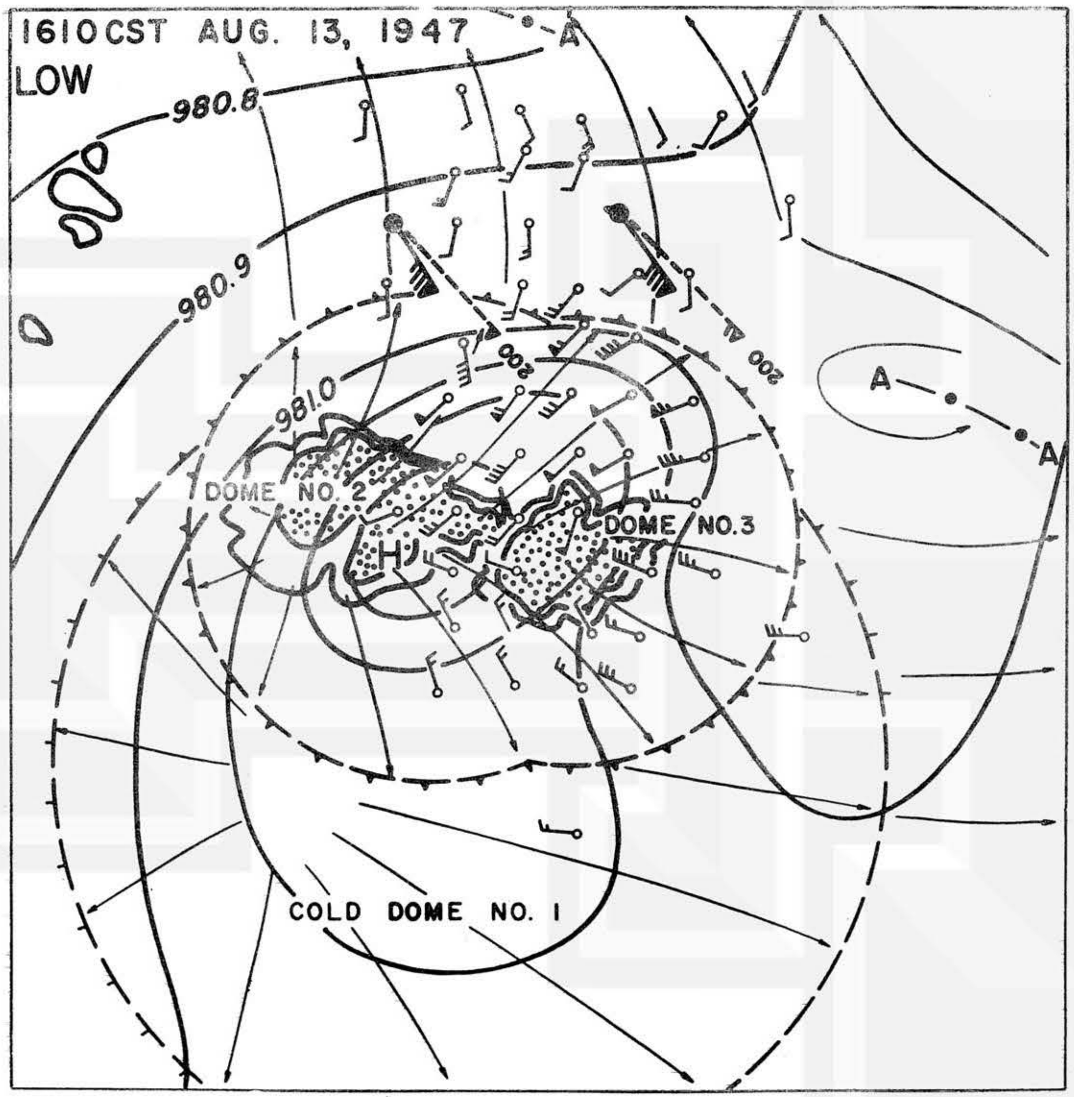
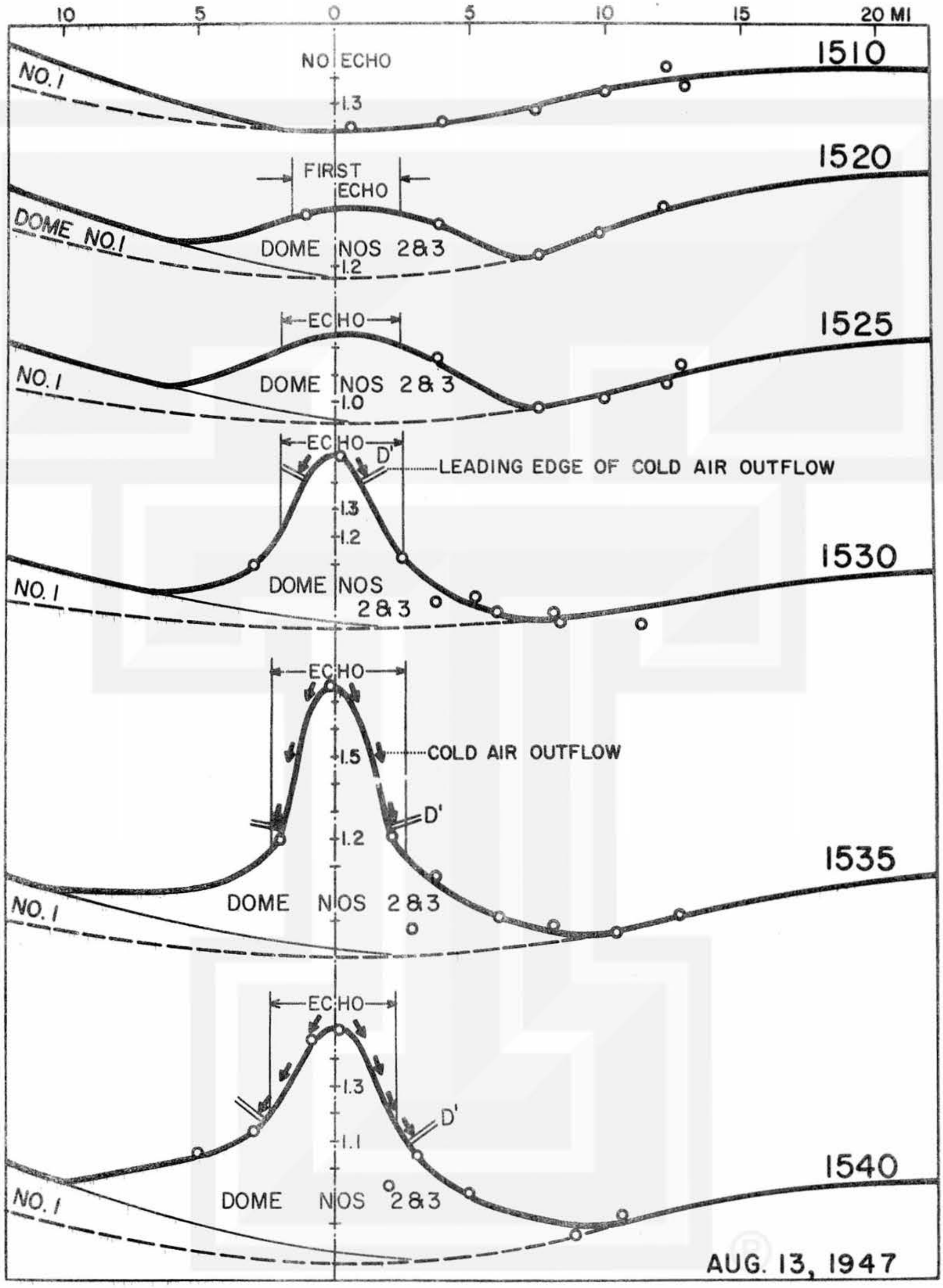

1610 CST AUG. 13, 1947
LOW
980.8
980.9
981.0
200
200 A
A
A
DOME NO. 2
DOME NO. 3
H
COLD DOME NO. 1

FIG. 9



10
5
0
5
10
15
20 MI
NO ECHO
1510
NO. 1
1.3
FIRST
ECHO
1520
DOME NO. 1
DOME NOS 2&3
1.2
ECHO
1525
NO. 1
DOME NOS 2&3
1.0
ECHO
D'
LEADING EDGE OF COLD AIR OUTFLOW
1.3
1.2
1530
NO. 1
DOME NOS
2&3
ECHO
COLD AIR OUTFLOW
1.5
D'
1.2
1535
NO. 1
DOME NOS 2&3
ECHO
1.3
D'
1.1
1540
NO. 1
DOME NOS 2&3
AUG. 13, 1947

FIG. 10

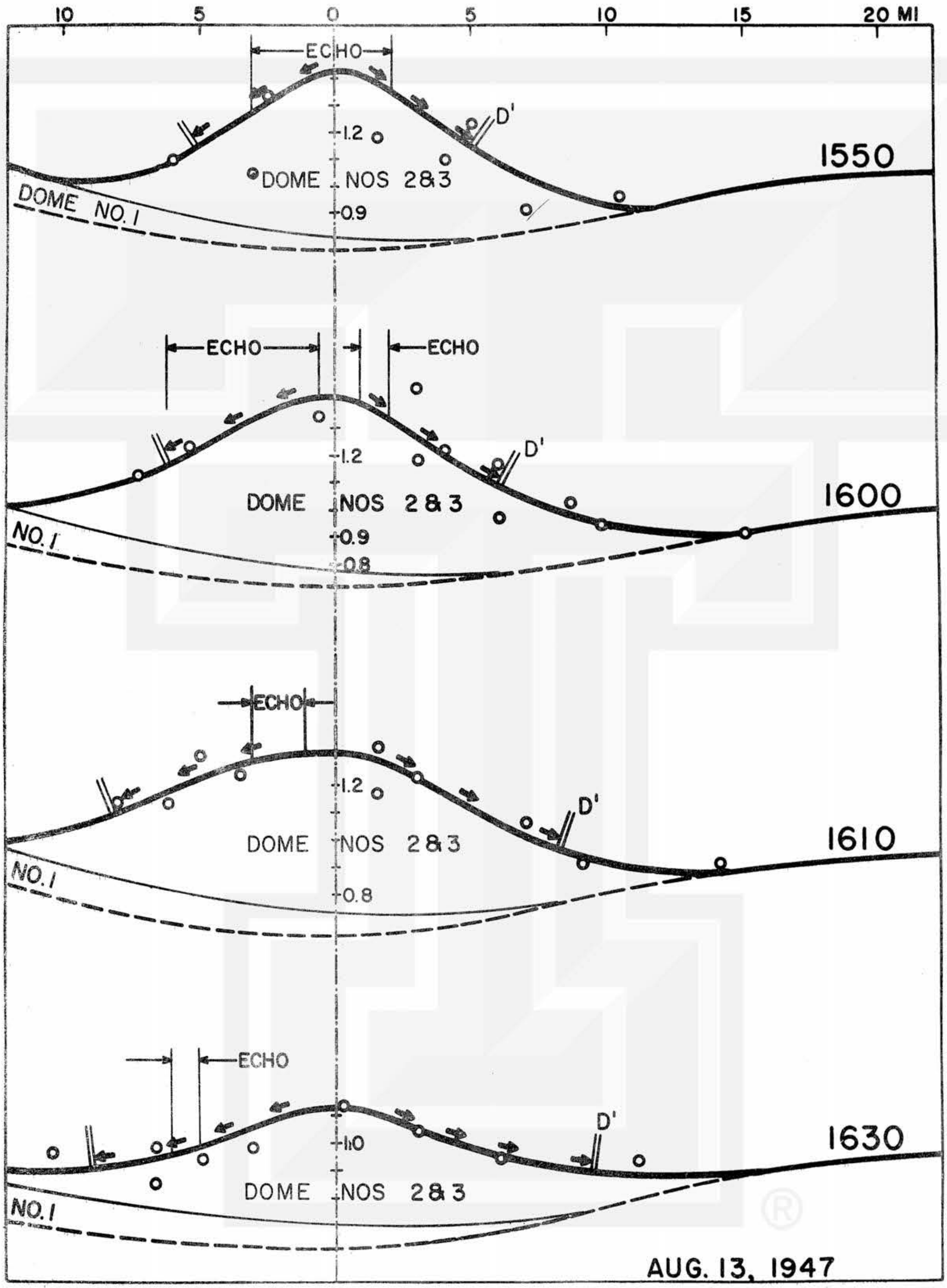

10
5
0
5
10
15
20 MI
ECHO
1.2
DOME NOS 2&3
0.9
DOME NO. 1
D'
1550
ECHO
ECHO
1.2
DOME NOS 2&3
0.9
0.8
NO. 1
D'
1600
ECHO
1.2
DOME NOS 2&3
0.8
NO. 1
D'
1610
ECHO
1.0
DOME NOS 2&3
NO. 1
D'
1630
AUG. 13, 1947

FIG. 11

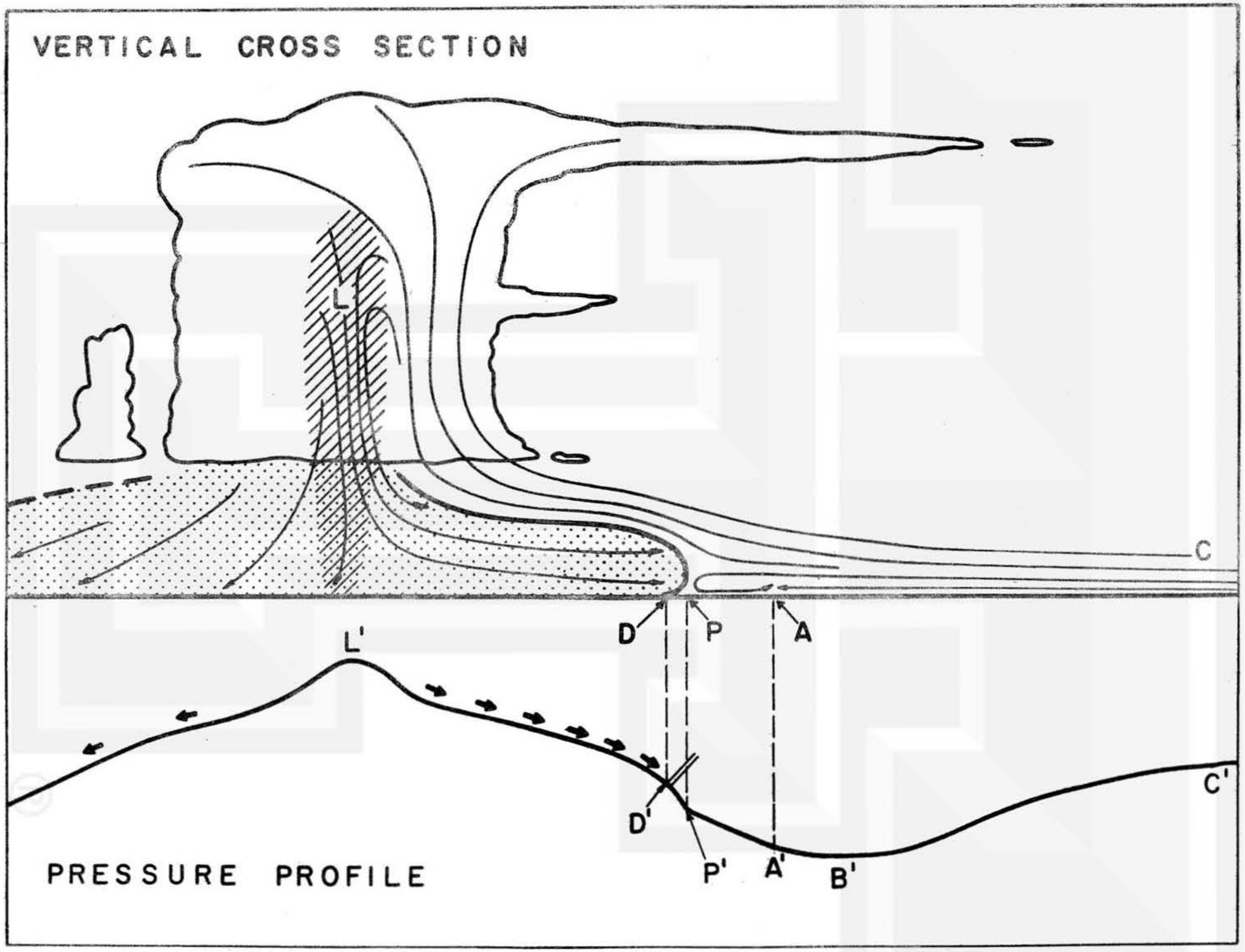
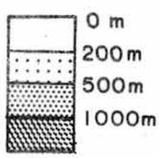


FIG. 12


Oslo
Stockholm
Edingburgh
Dublin
Copenhagen
Hamburg
London
Hague
Hanover
Berlin
Warszawa
Brussels
Bonn
Paris
Prahg
München
Wien
Bern
Budapest
Milano
Beigrad
Bucharest
Barcelona

FIG. 13


0 m
200m
500m
1000m

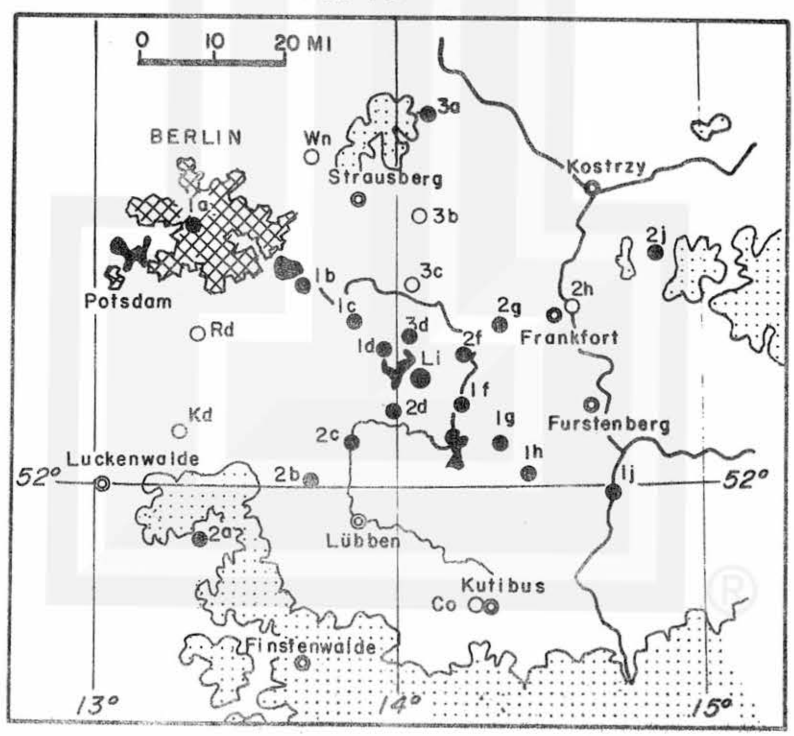

0 10 20 MI
BERLIN
Wn
Strausberg
3a
3b
3c
3d
Kostrzy
1a
1b
1c
1d
Li
1f
1g
1h
1j
2a
2b
2c
2d
2f
2g
2h
2j
Potsdam
Rd
Frankfort
Kd
Furstenberg
Luckenwalde
52°
Lübben
Kutibus
Co
Finstenwalde
13°
14°
15°

FIG. 14

FIG. 15

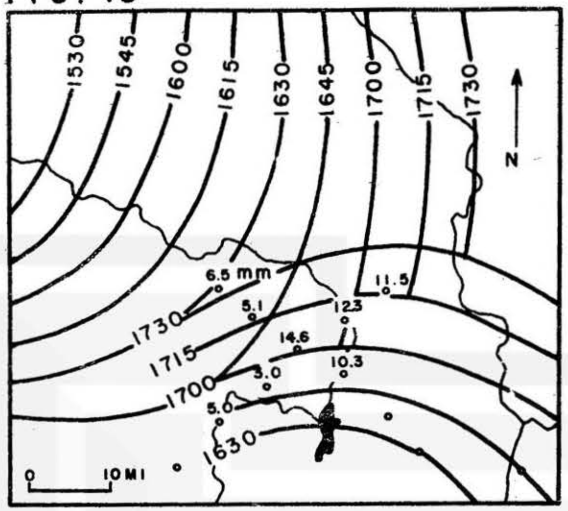


FIG. 16

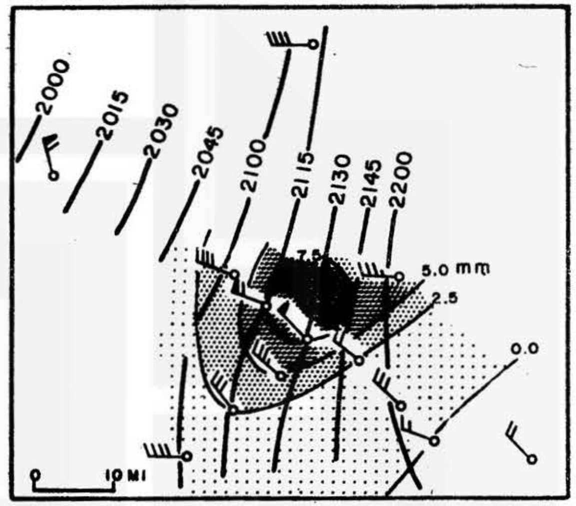


FIG. 17

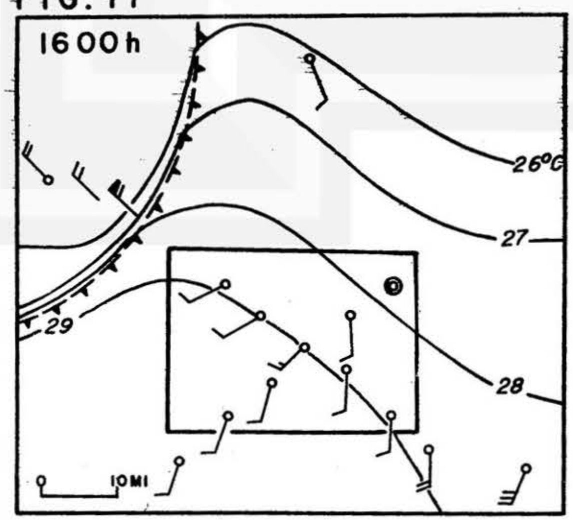


FIG. 18

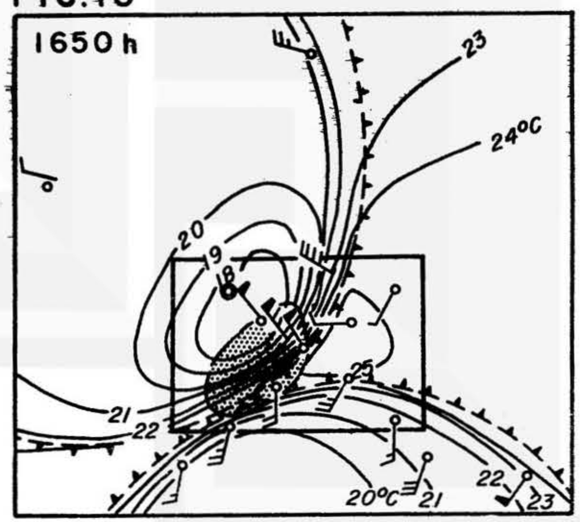


FIG. 19

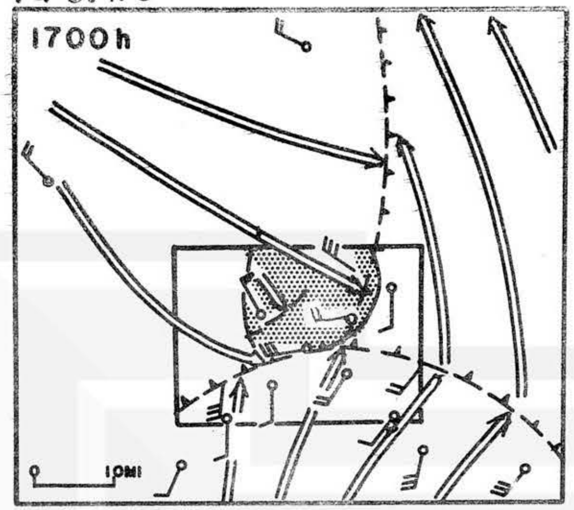


FIG. 20

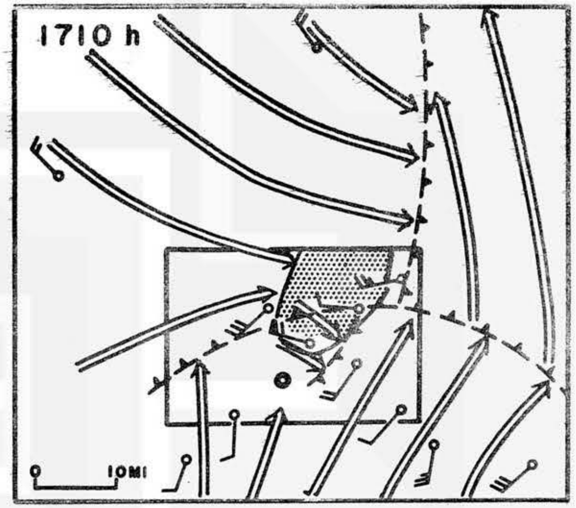


FIG. 21

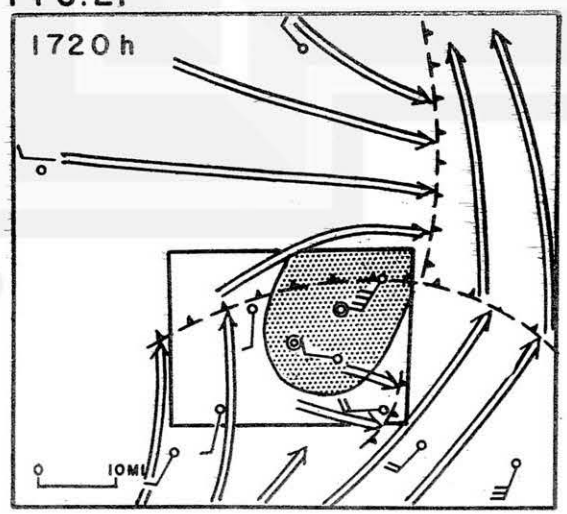
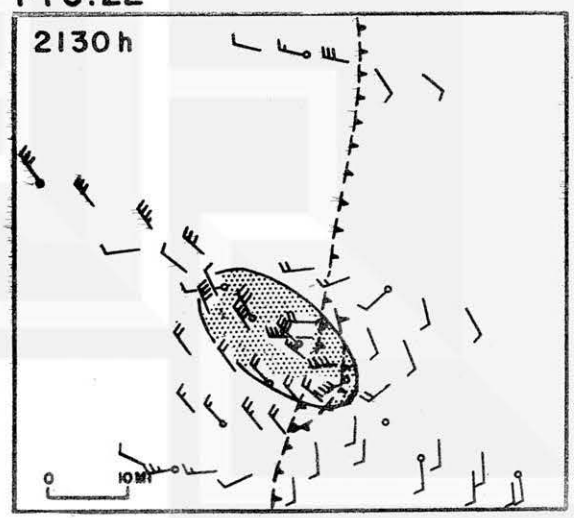


FIG. 22



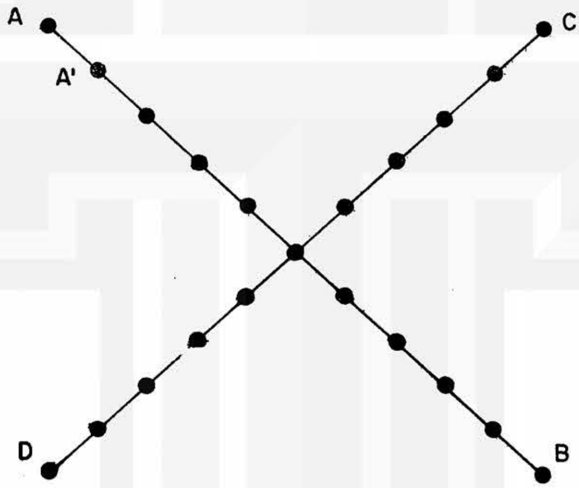


FIG. 23

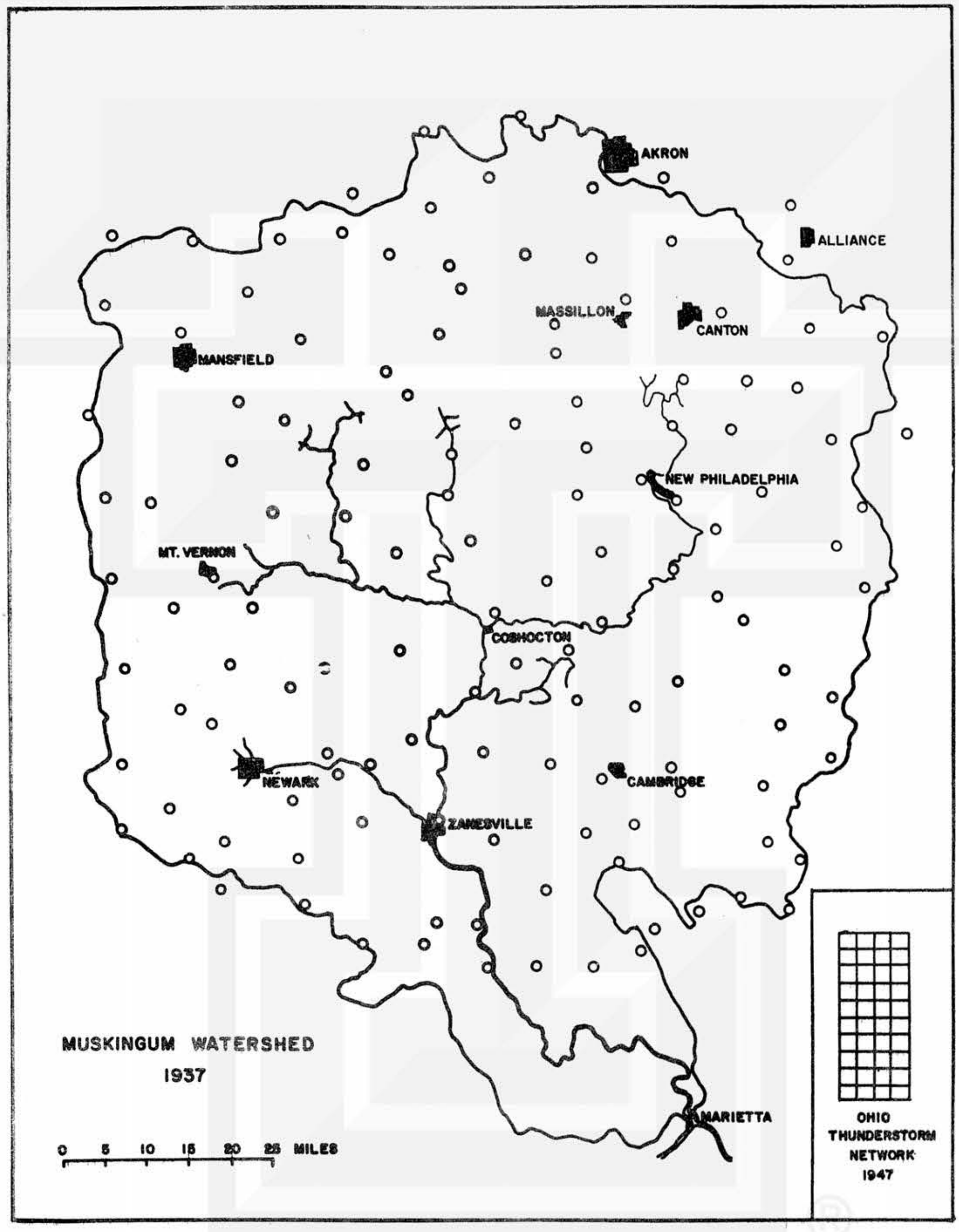

AKRON
ALLIANCE
MASSILLON
CANTON
MANSFIELD
NEW PHILADELPHIA
MT. VERNON
COSHOCTON
NEWARK
CAMBRIDGE
ZANESVILLE
MARIETTA
MUSKINGUM WATERSHED
1937
0 5 10 15 20 25 MILES
OHIO
THUNDERSTORM
NETWORK
1947

FIG. 24

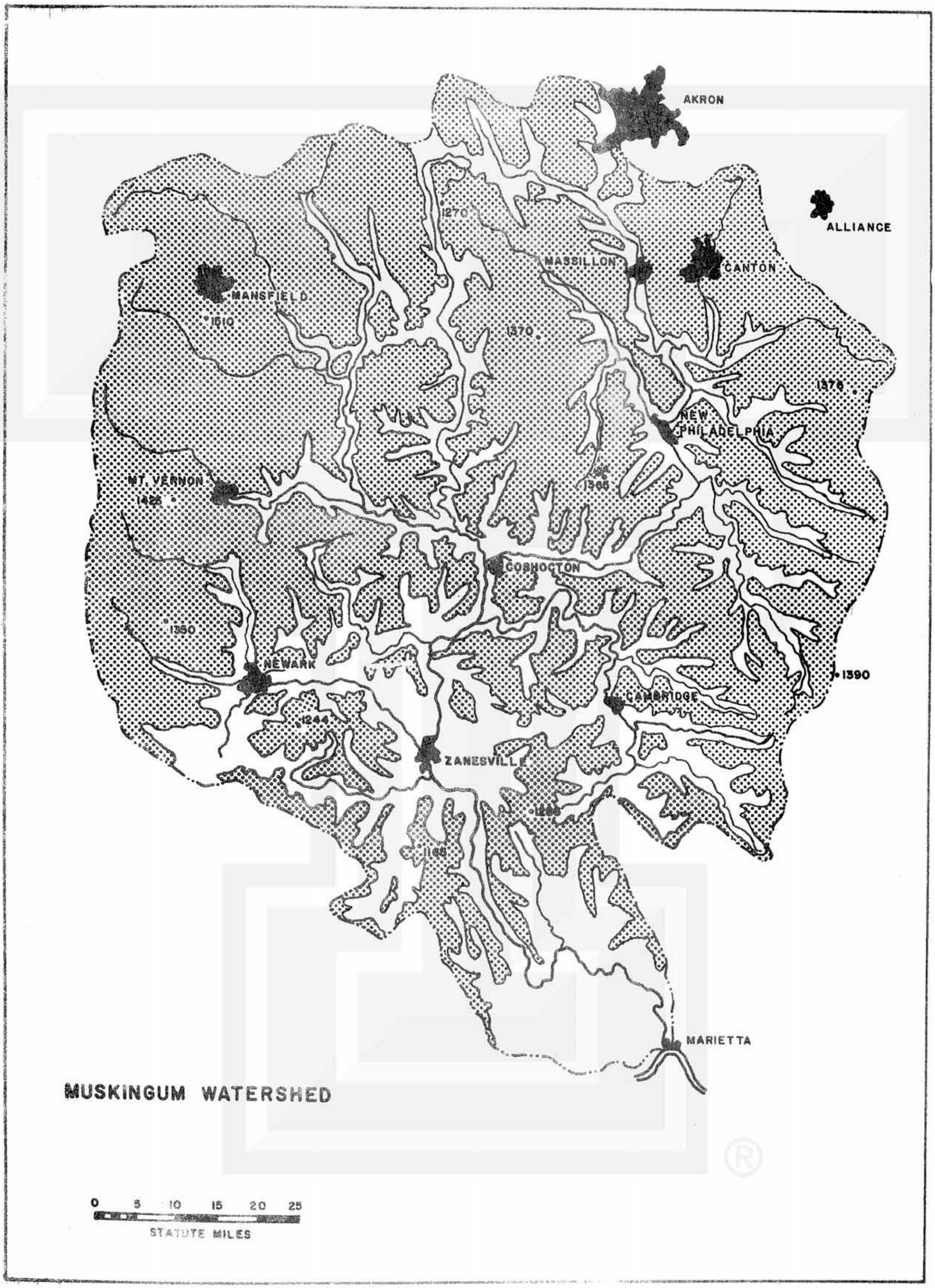

AKRON
ALLIANCE
MASSILLON
CANTON
MANSFIELD
1510
1270
1370
NEW PHILADELPHIA
MT. VERNON
COSHOCTON
NEWARK
1390
CAMBRIDGE
1244
ZANESVILLE
MARIETTA
MUSKINGUM WATERSHED
0 5 10 15 20 25
STATUTE MILES

FIG. 25

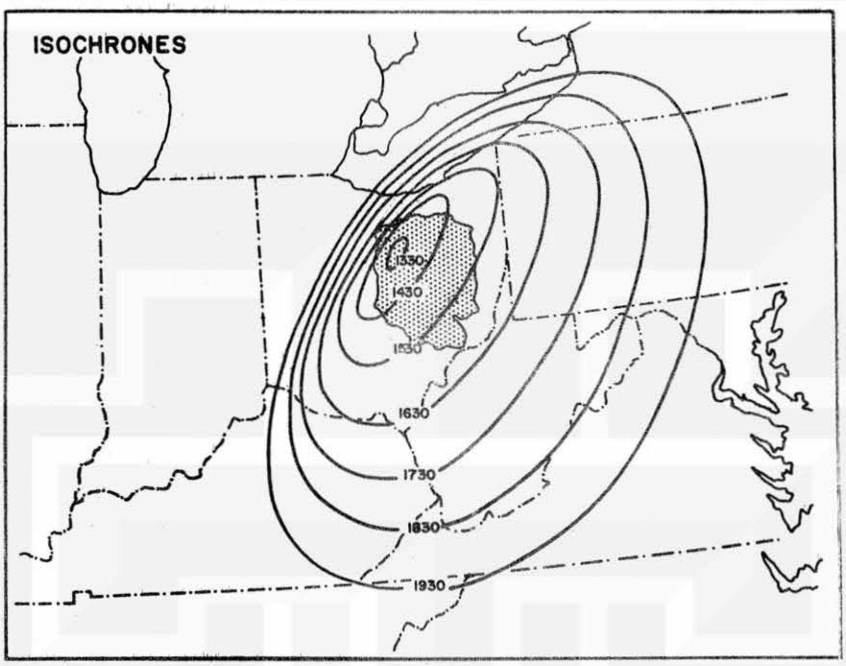

ISOCHRONES
1330
1430
1530
1630
1730
1830
1930

FIG. 26

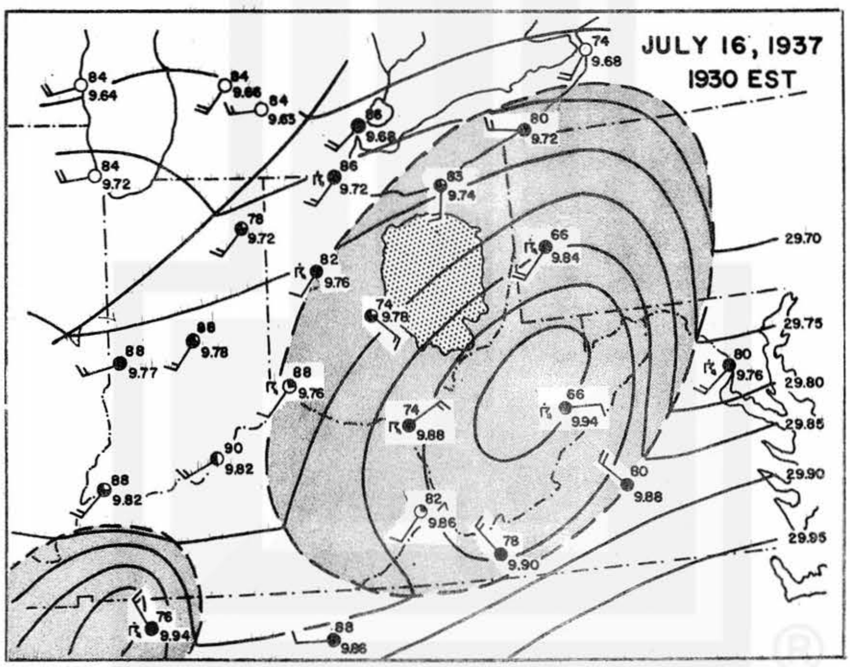

JULY 16, 1937
1930 EST
29.70
29.75
29.80
29.85
29.90
29.95

FIG. 27

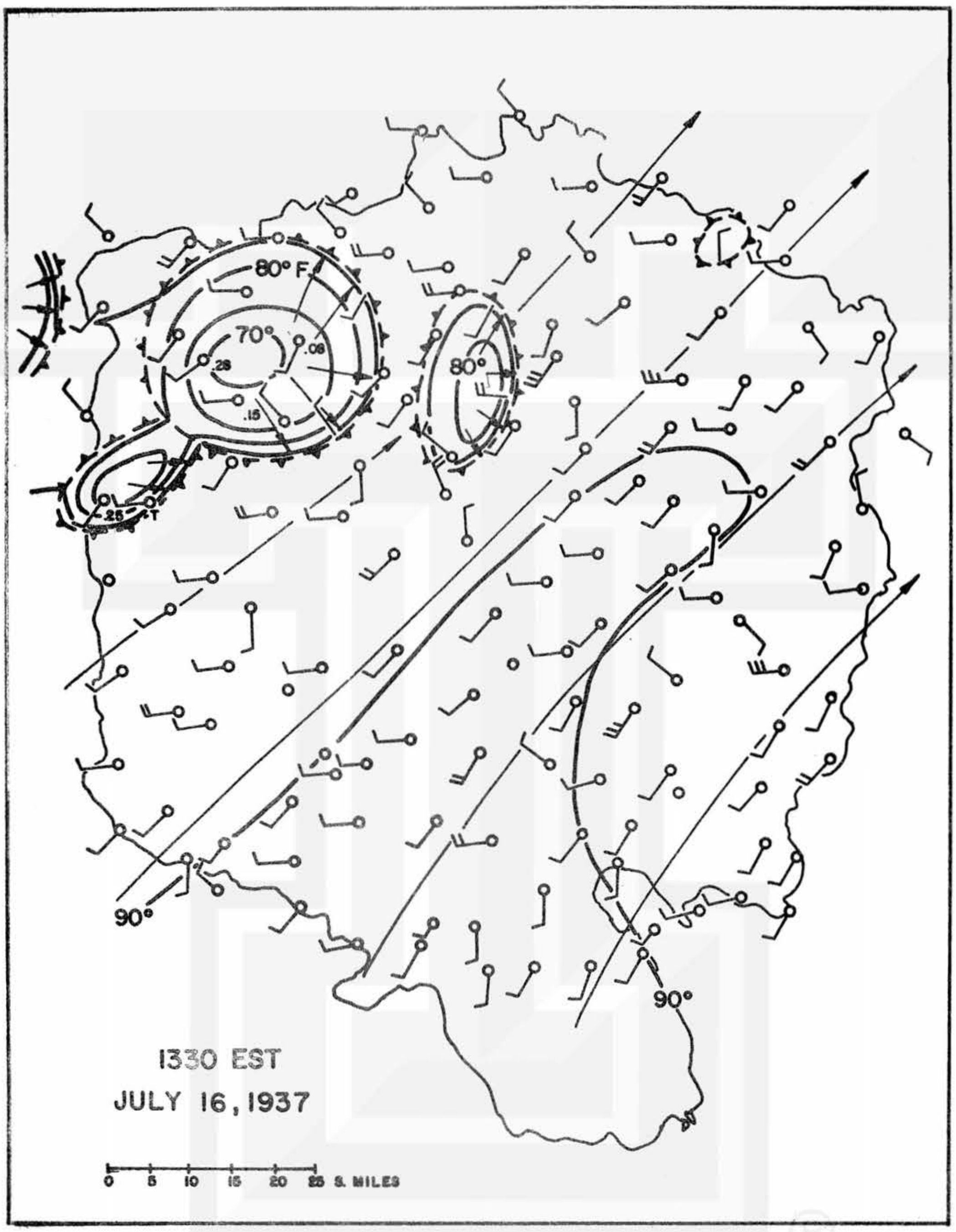

80° F.
70°
80°
.28
.08
.15
.25
T
90°
90°
1330 EST
JULY 16, 1937
0 5 10 15 20 25 S. MILES

FIG. 28

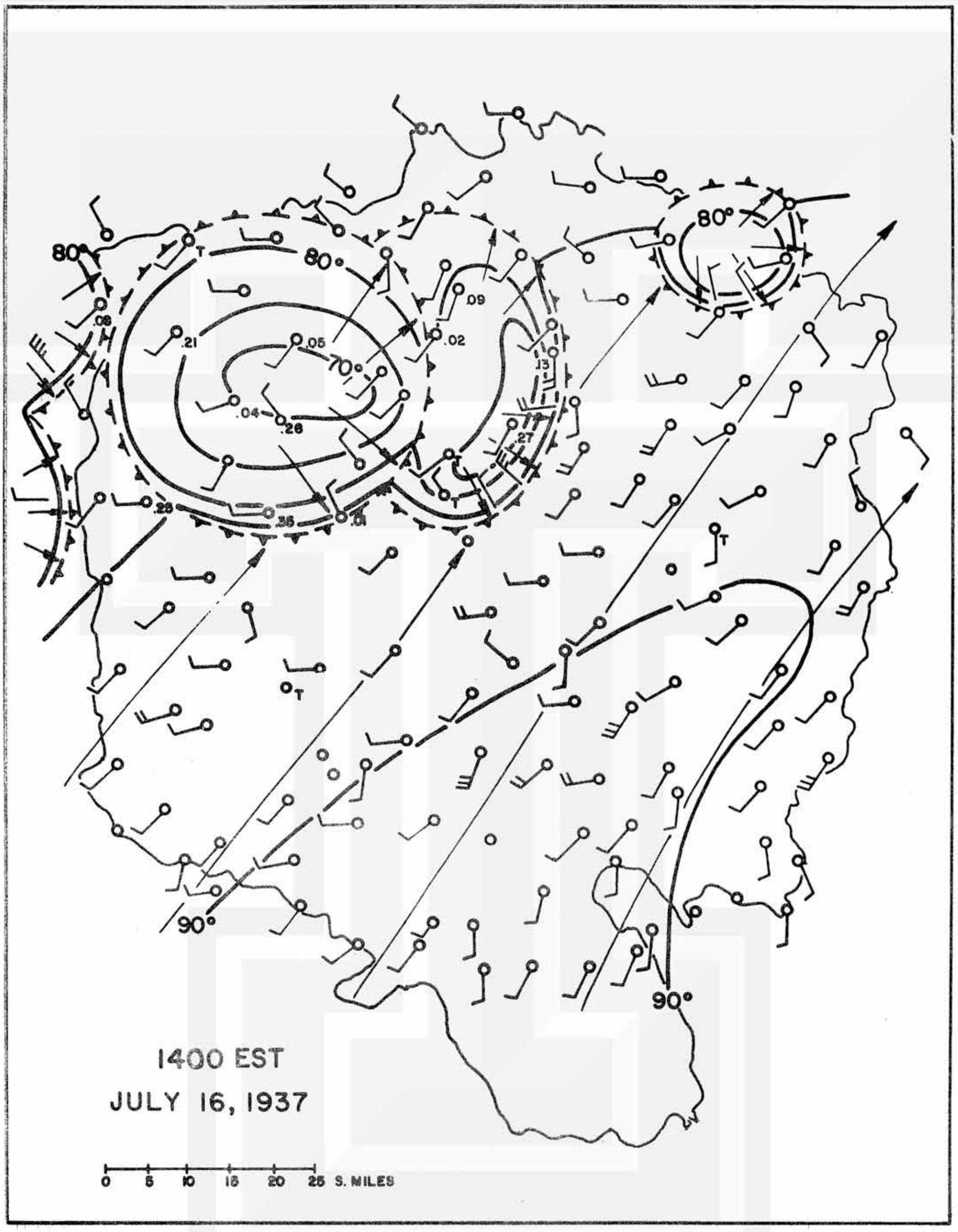


FIG. 29

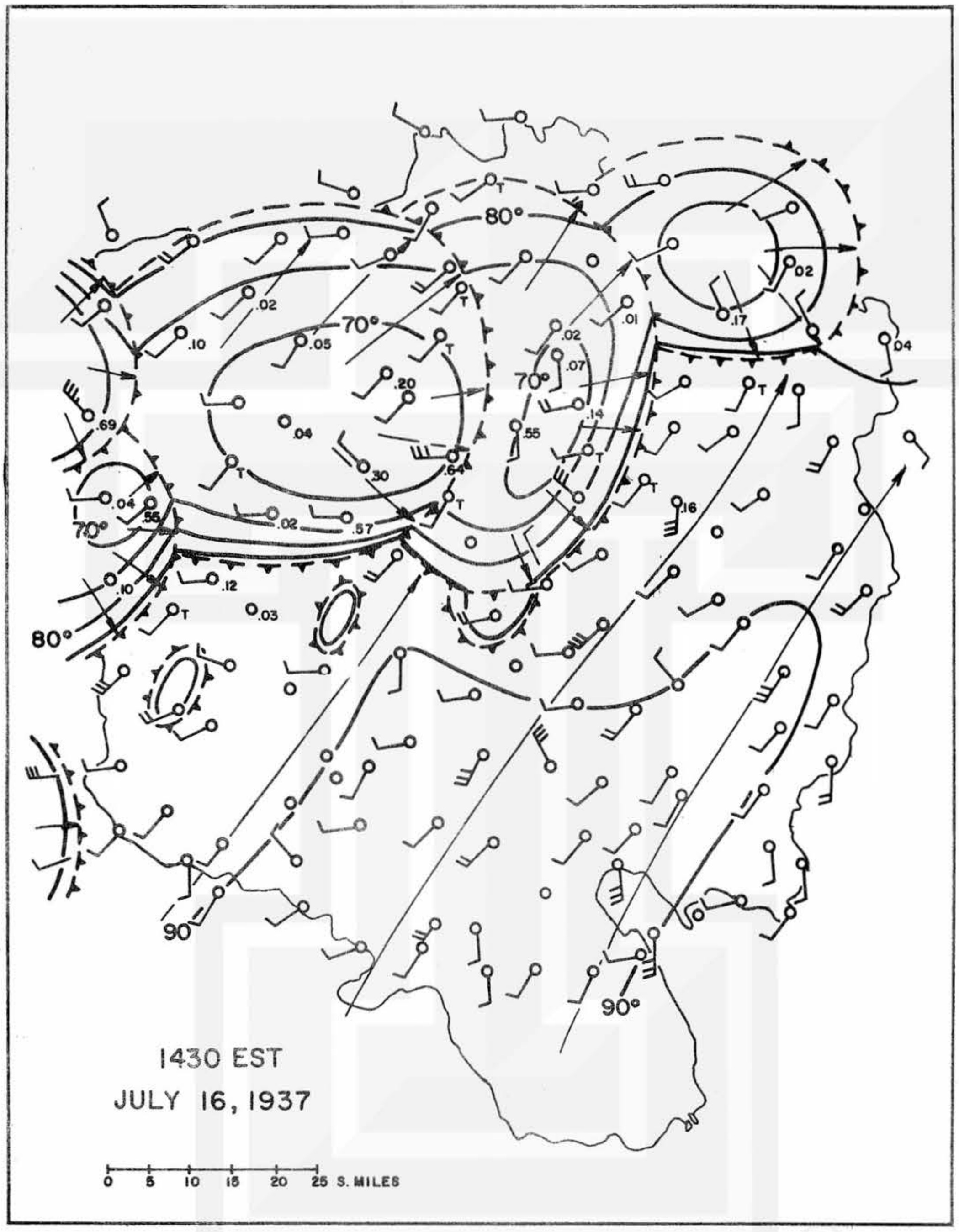


FIG. 30

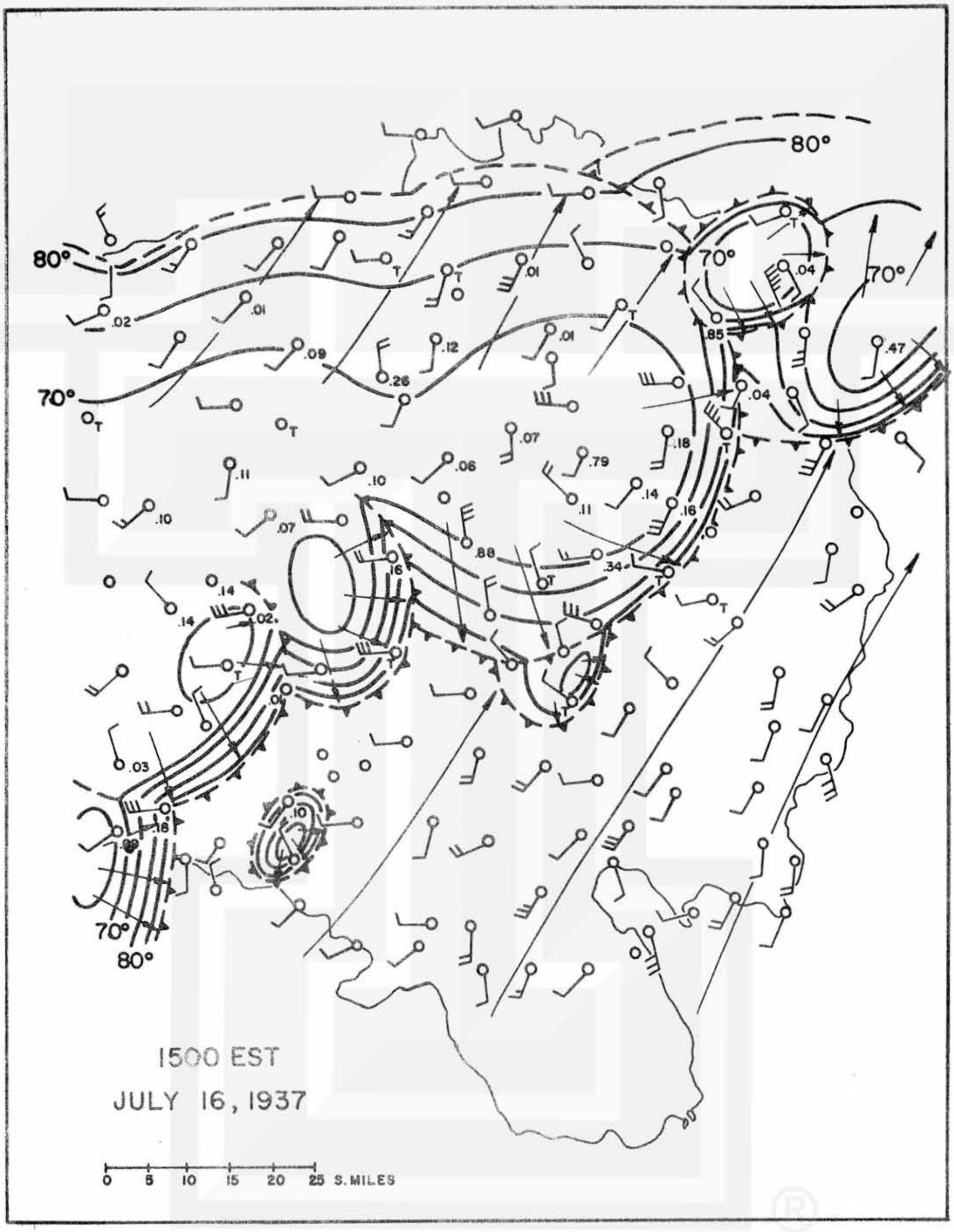


FIG. 31

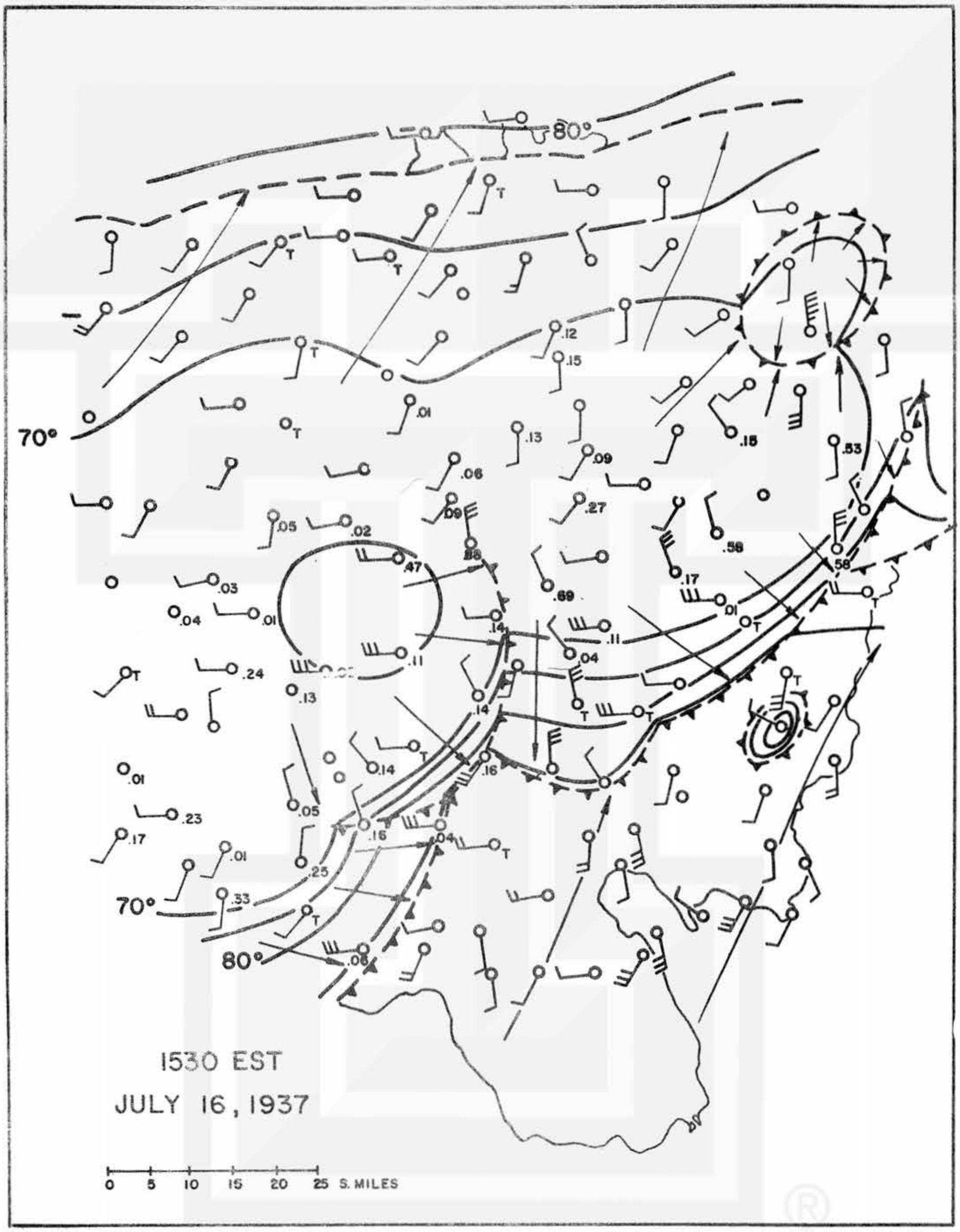


FIG. 32

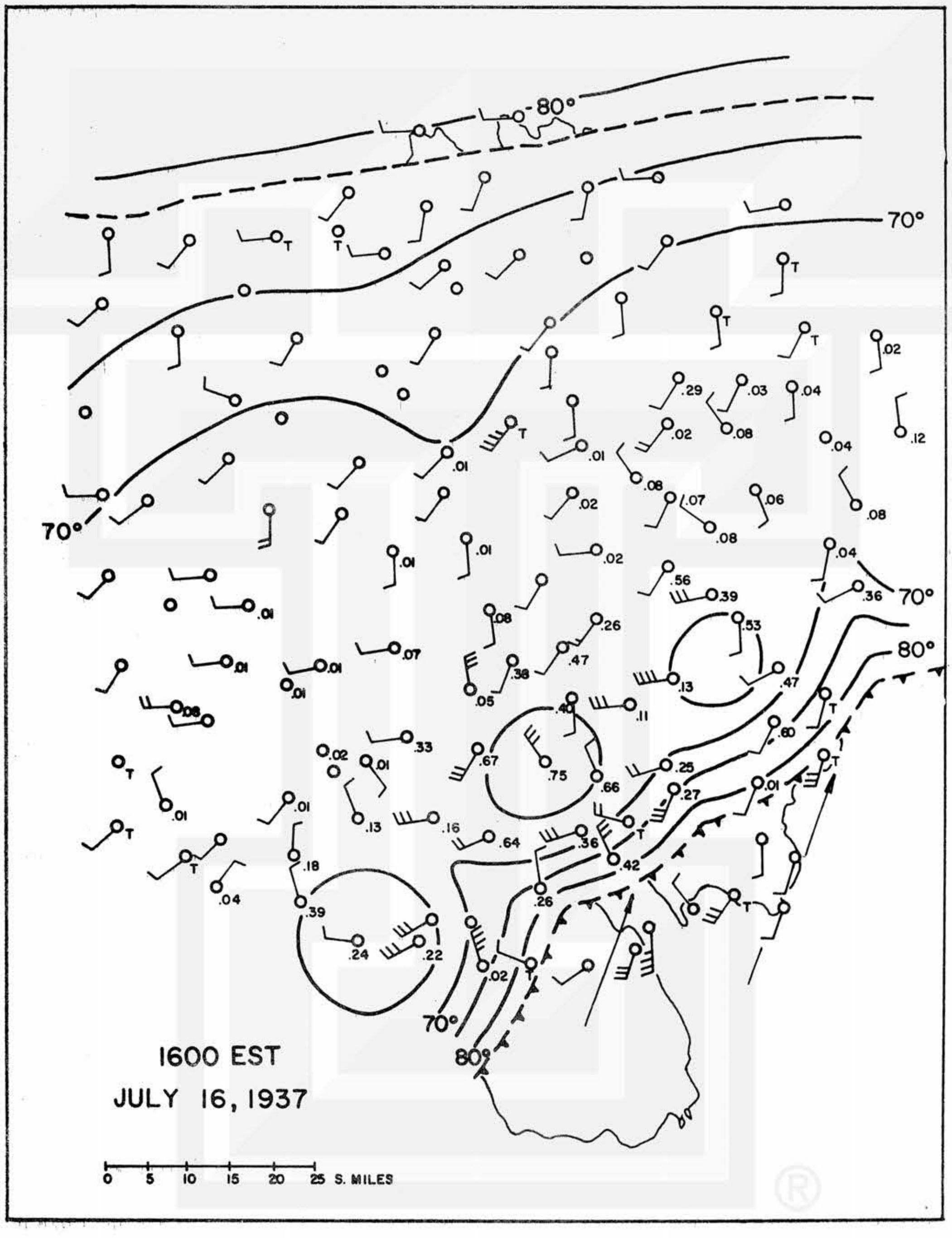


FIG. 33